MONTHLY WEATHER REVIEW

CLEVELAND ABBE, Editor.

VOL. 42, NO. 12.
W. B. NO. 543.

DECEMBER, 1914

CLOSED FEB. 1, 1915
ISSUED MAR. 16, 1915

INTRODUCTION.

During the summer of 1913 the Secretary of Agriculture established a board to reorganize the system of publications of the Department of Agriculture. In accordance with the proceedings of the board and the suggestions from representatives of the Weather Bureau, the "Bulletin of the Mount Weather Observatory" ceased to be published with the completion of its volume 6. Any subsequent contributions from the members of the research staff that would have been proper for that Bulletin will be incorporated in the MONTHLY WEATHER REVIEW. The climatological service of the Weather Bureau will be maintained in all its essential features, but its publications, so far as they relate to purely local conditions, will be incorporated in the monthly reports for the respective States, Territories, and colonies.

Beginning with December, 1914, the material for the MONTHLY WEATHER REVIEW will be prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office. Occasional original papers by prominent students of seismological phenomena.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto.

In general, appropriate officials will prepare the seven sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions that during recent years have been prepared by the 12 respective "district editors," will be omitted from the MONTHLY WEATHER REVIEW, but will in future be collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month whose name appears on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are especially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Central Meteorological and Magnetic Observatory of Mexico.
The Director General of Mexican Telegraphs.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.
The General Superintendent United States Life-Saving Service.

79709—15——1

SECTION I.—AEROLOGY.

SOLAR RADIATION INTENSITIES AT WASHINGTON, D. C., DURING OCTOBER, NOVEMBER, AND DECEMBER, 1914.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Weather Bureau, Washington, D. C., Jan. 12, 1915.]

As stated in this REVIEW for September, 1914 (p. 520), most of the solar radiation apparatus that had been in use at Mount Weather, Va., was transferred at the end of September to rooms in the American University, Washington, D. C., where radiation investigations are now being conducted in cooperation with that university. Advantage was taken of the unavoidable interruption in the record to restandardize the Marvin pyrheliometer, and during October and November all radiation measurements were made with Smithsonian silver-block pyrheliometer No. 1.

The American University (lat. = 38° 56′ N., long. = 77° 4′ W.) is on a plateau about 5½ miles northwest of the United States Capitol, 4 miles northwest of the White House, and 1½ miles northwest of the United States Naval Observatory. There are only a few scattered residences within a mile of it in any direction. Beyond this limit is open country to the west and south, much of it woodland, scattered suburban villages to the north, and the residence section of Washington to the east and southeast. There are no manufacturing establishments within about 3 miles, and the only steam railroad within a radius of about 5 miles is a spur over which freight cars are hauled at infrequent intervals. The university is therefore practically free from city influences, except with east and southeast winds, when the sky is apt to be overcast with clouds.

The Marvin pyrheliometer is exposed from windows on the second floor of the College of History, 26 feet above the ground, and 418 feet (127.4 m.) above sea level. A window facing southeast affords continuous exposure to the sun from sunrise to noon, and a window facing southwest affords continuous exposure from noon until sunset. The pyrheliometer is exposed on a shelf just outside the window, but is protected from high winds by the wide window jambs.

A Callendar pyrheliometer is exposed on the top of a ventilating flue near the center of the building, 59 feet above the ground, and 451 feet (137.5 m.) above sea level. A nocturnal radiation instrument is exposed on the top of the same flue, and a Pickering polarimeter exposed from a platform on the roof, is at about the same height.

In Table 1 are summarized the solar radiation measurements made during the months of October, November, and December, 1914. Those for October 1 and 2 were made from the roof of the central office of the Weather Bureau, 3 miles southeast of the university, and at an elevation of about 130 feet (39.6 m.) above sea level. The first readings at the university were obtained on October 21, and all subsequent readings have been made at that place.

For details relative to the number and frequency of radiation measurements and the method of interpolating readings to the air masses given in the headings of the table the reader is referred to pages 138 and 310 of the current volume of the REVIEW.

TABLE 1.—*Solar radiation intensities at Washington, D. C., during October, November, and December, 1914.*

[Gram-calories per minute per square centimeter of normal surface.]

Date.	Air masses.									
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1914.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
A. M.										
[1] Oct. 2	1.12	1.05								
28	1.39									
31	1.31									
Means	1.27	(1.05)								
P. M.										
[1] Oct. 1	1.34	1.25	1.17	1.09	1.02	0.97				
[2] 21	1.18	1.07								
30	1.39									
31		1.17	1.09	1.01	0.94	0.87	0.81	0.76		
Means	1.30	1.19	(1.13)	(1.05)	(0.98)	(0.92)	(0.81)	(0.76)		
A. M.										
Nov. 2		1.08	0.99	0.91						
3		1.13	1.05		0.90	0.84	0.80			
4		1.03	0.93							
7		0.70	0.58							
10		1.37	1.20	1.20	1.13	1.08	1.02	0.97	0.92	0.87
12		1.14	1.05	0.94	0.83	0.77	0.72	0.67	0.60	
17			1.30	1.23	1.16	1.11	1.04	0.96	0.92	0.91
18		1.11								
20				0.60						
21		1.26	1.16			0.97	0.91	0.84	0.80	
23		1.29	1.11							
24		1.16	1.13	1.10						
Means		1.13	1.06	1.00	1.01	0.95	0.90	0.86	0.81	(0.89)
P. M.										
Nov. 2		1.17								
4		0.92	0.86	0.76	0.64	0.58	0.52			
5		1.16	1.04	0.92	0.81	0.71	0.62	0.55		
6		1.20	0.91	0.81	0.74	0.71	0.70	0.57		
7		0.80	0.64	0.45						
9		1.33	1.22							
10		1.34	1.20							
13		1.08	0.87	0.79						
16		1.34	1.26	1.14	1.03	0.96	0.90	0.85	0.81	0.78
23		1.29	1.14	1.03	0.97	0.92	0.87	0.81	0.74	0.67
24		1.27	1.19	1.05	0.94					
Means		1.17	1.03	0.87	0.86	0.78	0.72	0.70	(0.78)	(0.72)
A. M.										
Dec. 12						0.63	0.57	0.52	0.47	
15		1.34	1.30	1.17	1.11	1.04	0.97	0.91	0.85	
16		1.34	1.27	1.19	1.11	1.04	0.98	0.92	0.86	0.82
17		1.24	1.12	1.03	0.96	0.88	0.83	0.76	0.71	0.67
18		1.07	0.93	0.81	0.72	0.66	0.61	0.56	0.52	0.48
26		1.51	1.42							
Means		1.30	1.21	1.05	0.98	0.85	0.79	0.73	0.68	0.66
P. M.										
Dec. 14			1.02	0.90	0.81	0.76	0.71	0.67	0.65	
15			1.26	1.18	1.10	1.02	0.95	0.90	0.85	0.82
16			1.24	1.16	1.09	1.04	0.99	0.94	0.89	0.85
17			1.14	1.05	0.95	0.85	0.78	0.73	0.69	0.65
18			1.00	0.93	0.83	0.74	0.67	0.63	0.58	
21			1.23							
23			1.19							
26			1.41	1.32	1.24	1.16	1.09	1.04	1.00	0.97
27			1.22	1.14			0.94	0.89	0.84	0.80
Means			1.19	1.10	1.00	0.93	0.88	0.83	0.79	0.82

[1] Observations taken at central office.
[2] First observation taken at the American University.

In Table 1 the mean values corresponding to air-mass 2 for December are higher, and for November they are lower, than the corresponding normals published in the Bulletin of the Mount Weather Observatory, v. 5, p. 182, table 3. These normals are based on observations made at the Weather Bureau, Washington, between 1905 and 1910.

The maximum radiation intensities for air-mass 2 in November and December exceed the corresponding maxima obtained at Mount Weather in 1913. Table 2 shows that the readings obtained on December 26 exceed any hitherto obtained in the vicinity of Washington with the sun at a zenith distance of 60° or more. The table shows that they are not so high as readings that have been obtained at Madison, Wis., at an elevation of 974 feet (296.9 m.) above sea level, or intermediate to the elevations of Mount Weather and the American University. Some observations on the increase of insolation with elevation, published in the Bulletin of the Mount Weather Observatory, v. 6, p. 107, indicate that while in hazy weather, and especially in the warm part of the year when the atmosphere contains considerable moisture, differences of from 500 to 1,000 feet in elevation may cause several per cent difference in radiation intensities, with an atmosphere comparatively free from dust and moisture the effect of such differences in elevation is hardly appreciable.

TABLE 2.—*Maximum solar radiation intensities.*

[Gram-calories per minute per square centimeter of normal surface.]

Station.	Air masses.										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
	Gr.-cal.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Mount Weather, Va.	1.53	1.48	1.43	1.34	1.27	1.20	1.15	1.09	1.04	1.00	0.96
Washington, D. C.[1]	1.53	1.49	1.41	1.32	1.23	1.15	1.10	1.04	0.96	.....	.....
Washington, D. C.[2]	.....	.....	1.51	1.42	1.32	1.24	1.16	1.09	1.04	1.00	0.97
Madison, Wis.	1.58	1.61	1.57	1.58	1.47	1.36	1.28	1.18	1.17	1.12	.....

[1] Highest observed at Washington, D. C., previous to Dec. 26, 1914.
[2] Readings on Dec. 26, 1914.

The meteorological conditions on December 26 were conducive to an atmosphere unusually free from dust and water vapor. Cold northwest winds out of an area of high pressure prevailed, and the region from which they came, as well as that immediately surrounding Washington, was covered with snow that fell on the 24th. At 8 a. m. of the 26th the temperature at the Weather Bureau, Washington, was 8°F., or −13°C., and the vapor pressure was 1.19 mm. At 8:30 p. m. the temperature at the University was −11.5°C., and the vapor pressure was 1.10 mm. According to Abbot[1] the absorption of solar radiation by the vapor content of the atmosphere indicated by this vapor pressure, with the sun at zenith distance 60°, would not exceed 6 per cent.

In Table 3 are given the readings on which the tabulated values for the A. M. of December 26 are based. In Table 4 are given comparative readings of Marvin pyrheliometer No. 3 and Smithsonian silver-disk pyrheliometer No. 1. These were made on January 7, 1915, the first favorable day for such readings after December 26. It will be noted that the probable error in the mean of series of readings in either Table 3 or 4 is very small, and that the two pyrheliometers are in practical accord.

[1] Annals of the Astrophysical Observatory of the Smithsonian Institution, v. 2, p. 130.

TABLE 3.—*Radiation measurements made before noon of Dec. 26, 1914.*

Sun's hour angle from noon.	Sun's altitude.	Air mass.	Radiation (Q.).
H. m.	° ′		*Gr.-cal.*
2 04	21 17	2.74	1.386
2 03	21 22	2.72	1.385
2 02	21 28	2.71	1.380
2 01	21 34	2.70	1.388
2 00	21 40	2.69	1.383
1 59	21 46	2.68	1.385
0 23	27 29	2.16	1.480
0 22	27 30	2.16	1.474
0 21	27 31	2.16	1.478
0 20	27 32	2.16	1.480
0 19	27 33	2.16	1.481
0 18	27 34	2.16	1.475
0 17	27 35	2.15	1.478
0 16	27 36	2.15	1.489
0 15	27 37	2.15	1.494
0 14	27 38	2.15	1.486
0 13	27 39	2.15	1.478
0 12	27 39	2.15	1.481
0 11	27 40	2.15	1.486
0 10	27 41	2.14	1.480

TABLE 4.—*Comparative readings of Smithsonian pyrheliometer No. 1 and Marvin No. 3.*

Sun's hour angle from noon.	Sun's altitude.	Air mass.	Radiation.	
			Marvin No. 3.	Smithsonian No. 1.
H. m.	° ′		*Gr.-cal.*	*Gr.-cal.*
0 38	28 01	2.12	1.331	.....
0 37	28 03	2.12	1.332	.....
0 36	28 05	2.12	1.332	1.327
0 35	28 07	2.12	1.334	.....
0 34	28 09	2.12	1.338	1.345
0 33	28 11	2.11	1.336	.....
0 32	28 13	2.11	1.338	1.321
0 31	28 14	2.11	1.339	.....
0 30	28 16	2.11	1.345	1.342
0 29	28 18	2.10	1.354	.....
0 28	28 19	2.10	1.359	1.346
0 27	28 21	2.10	1.361	.....
0 26	28 22	2.10	1.356	1.344
0 25	28 24	2.10	1.356	.....
0 24	28 25	2.10	1.361	1.326
0 23	28 26	2.10	1.359	.....
0 22	28 27	2.10	1.354	1.349
0 21	28 28	2.09	1.348	.....
0 20	28 29	2.09	1.345	1.348
0 19	28 30	2.09	1.346	.....
0 18	28 31	2.09	1.348	1.350
0 17	28 32	2.09	1.348	.....
0 16	28 33	2.09	1.344	1.346
0 15	28 34	2.08	1.341	.....
Means.....	.....	.....	1.346	1.340

Skylight polarization measured at a point 90° from the sun and in the same vertical circle, with the sun at zenith distance 60°, averaged 65 per cent in November and 62 per cent in December, excluding from the latter month all measurements made after the snowfall of the 24th. The maximum for November was 72 per cent and for December 66 per cent. Comparing these with the averages and departures published in the Bulletin of the Mount Weather Observatory, Volume 3, page 114, Table 16, it will be seen that they are 6 per cent and 3 per cent, respectively, above the average. The November maximum is as high as any previously measured in Washington.

The above observations, taken in connection with the readings obtained at Mount Weather, Va., in September, 1914, and published on page 520 of the current volume of this REVIEW, indicate unusually clear skies in the vicinity of Washington during the latter part of 1914.

PHOTOMETRIC MEASUREMENTS OF DAYLIGHT ILLUMINATION ON A HORIZONTAL SURFACE AT MOUNT WEATHER, VA.

By HERBERT H. KIMBALL, Professor of Meteorology.
[Dated Weather Bureau, Washington, D. C., Jan. 25, 1915.]

Measurements of the daylight illumination on a horizontal surface freely exposed to the sky, including that part of it occupied by the sun, or to the sky alone with the sun artificially eclipsed, were made at Mount Weather from September 17, 1913, to September 15, 1914. They were made at intervals throughout the day on most clear days, and also on cloudy days when the cloud layer was of sufficiently uniform thickness to permit of satisfactory light intensity measurements. Ordinarily in cloudy weather, and especially during the summer months, the light intensity varies so rapidly that measurements have little significance. The pressure of other work prevented photometric measurements during March and April, 1914.

The measurements were made with a Sharp-Millar photometer (1), and the character of the instrumental exposure is shown in this REVIEW for August, 1914, figures 3 and 4, opposite page 477. It was necessary to provide a milk glass screen, in addition to the two neutral glass screens *L* and *D* furnished with the instrument, to reduce daylight illumination to an intensity that could be measured by the photometer. This screen had a transmission coefficient of 1/288; and the two neutral glass screens had coefficients of 0.138 and 0.041, respectively, when used in connection with the milk glass screen.

It was also found necessary to provide two blue glass screens, VA and VIA, to reduce the light of the comparison lamp to the color of daylight, and to the color of the light from the sky alone, respectively. The transmission coefficient of VA was 0.235, and that of VIA was 0.112.

With the exception of a few measurements of twilight illumination, the milk glass screen was used in all light intensity measurements, and the neutral glass screen *L* in nearly all. It was sometimes omitted on clear days when the sun was near the horizon, and also on days with dense clouds. In summer near midday with a clear sky it was sometimes necessary to replace it with the neutral glass screen *D*.

The blue glass screen VA was also used in nearly all light intensity measurements. The color of the light from the comparison lamp transmitted by this screen matched very closely the color of the total light from the sky and sun, and also the light from an overcast sky. The light from the clear sky alone was decidedly blue in comparison with it, and in a few measurements of sky-light illumination blue glass screen No. VIA was employed. Experience demonstrated, however, that the increased accuracy of measurements obtained when using VIA, arising from a better color match, was more than offset by the disadvantage arising from the decrease in the intensity of the light from the comparison lamp transmitted by this screen.

The three following combinations of screens, and the accompanying factors to reduce scale readings on the photometer to foot-candles of illumination, will, therefore, apply to most of the photometric measurements made at Mount Weather.

(1) Milk glass, and blue glass VA,
Factor=288×0.235, =67.68.

(2) Milk glass, blue glass VA, and neutral glass *L*,

$$\text{Factor}=\frac{288\times 0.235}{0.138}=490.4.$$

(3) Milk glass, blue glass VA, and neutral glass *D*,

$$\text{Factor}=\frac{288\times 0.235}{0.041}=1651.$$

The United States Bureau of Standards furnished the milk glass screen and the two blue glass screens, and determined the transmission coefficients of all the screens. It also standardized the comparison lamp; but in order to eliminate the personal equation of the observer as far as possible the author made the final comparisons between this lamp and a standard lamp. The original comparisons consisted in determining the electric current required in the lamp circuit to give scale readings on the photometer expressed in foot-candles of illumination, with all the screens removed. In recomparisons made on November 8, 1913, January 3, 1914, June 16, 1914, and October 8, 1914, the current was adjusted to the amperage determined on the original test, and the illumination of the standard lamp was read by means of the photometer in the usual way. No change of consequence was detected in the comparison lamp until October 8, 1914, when its readings were about 5 per cent low. A graded correction of from 1 to 5 per cent has therefore been applied to the readings obtained after June 16, 1914.

The Bureau of Standards certificate states that the transmission coefficients of the various glass screens are correct to within 1 to 3 per cent. Most of the photometer readings were made by the writer. Each illumination measurement is the mean of three independent settings of the photometer, and the extreme difference in these individual readings is rarely more than 5 per cent. Some readings were made by Mr. I. F. Hand, and there is no evidence that his readings differ materially from my own. It is probable that the readings given are correct to within ±5 per cent.

TABLE 1.—*Photometric readings at Mount Weather, Va., on June 30, 1914.*

Sun's hour angle.	Sun's altitude.	Exposure.	Screens.	Photometric readings. 1	2	3	Mean.	Illumination.	Clouds.
A. M.									
h. m.	Deg.							Foot candles.	
5 55	14.3	Sky.....	VA+L.....	1.50	1.49	1.48	1.49	729	Few ci.
5 52	15.8	Total...	VA+L.....	7.25	7.22	7.20	7.22	3,542	Few ci.
4 45	28.5	Sky.....	VA+L.....	1.58	1.61	1.60	1.60	783	Few ci.
4 11	35.1	Total...	VA+L.....	10.2	10.2	10.2	10.2	4,979	Few ci.
2 58	49.1	Sky.....	VA+L.....	1.79	1.76	1.78	1.78	871	Few ci.
2 55	59.8	Total...	VA+L.....	16.5	15.5	16.0	16.0	7,827	Few ci.
1 42	62.2	Sky.....	VA+L.....	1.88	1.87	1.87	1.87	915	Few ci.
1 38	62.8	Total...	VA+D.....	5.80	5.75	5.85	5.80	9,576	Few ci.
0 41	71.9	Sky.....	VA+L.....	2.00	2.03	2.04	2.02	988	Few ci.
0 37	72.3	Total...	VA+D.....	5.95	5.91	6.08	5.98	9,873	Few ci.
P. M.									
0 49	71.1	Sky.....	VA+L.....	2.15	2.12	2.20	2.16	1,058	1 cu.
0 52	70.7	Total...	VA+D.....	5.80	6.00	5.80	5.87	9,691	1 cu.
2 48	51.2	Sky.....	VA+L.....	2.30	2.31	2.30	2.30	1,126	1 cu.
2 51	50.5	Total...	VA+L.....	15.9	15.6	15.8	15.8	7,728	1 cu.
4 48	28.0	Sky.....	VA+L.....	1.94	1.90	1.92	1.92	939	2 cu.
4 51	27.4	Total...	VA+L.....	7.20	7.19	7.30	7.23	3,547	2 cu.

Table 1 presents the readings recorded on June 30, 1914. For reasons given above these were increased by 1 per cent before they were included in the tabulation that follows. The exposure to the sky alone was effected by artificially eclipsing the sun by means of the screen shown at *D* in figure 4, opposite page 477 of the current volume of this REVIEW.

The data of Table 2 have been obtained by plotting observations similar to those in Table 1, taking illumination measurements as ordinates and the sun's hour angle from the meridian as abscissas, and drawing a smooth curve through the measurements of *total* illumination. A curve drawn through similar plottings of measurements

of *sky* illumination enables us to obtain the data in Table 3.

These latter curves enable us to interpolate sky-illumination values for the times at which measurements of the total illumination were obtained. The difference gives the solar illumination on a horizontal surface. Dividing this difference by the sine of the sun's altitude at the time of the observation gives the solar illumination on a surface normal to the direction of the incident solar rays. The logarithms of these latter values were plotted against the air masses, or approximately the secant of the sun's zenith distance at the time of observation; and the resulting curves, which under favorable sky conditions approximate straight lines, gave the data presented by Table 4.

A study of Tables 2 and 4 shows that from September to February, inclusive, at all hours of the day, solar illumination at normal incidence generally exceeds the total illumination on a horizontal surface; but that from May to August, inclusive, the illumination on a horizontal surface is in excess for from four to eight hours in the middle of the day. In general, the hazier the sky the greater and the longer continued is the midday excess of the total horizontal illumination over the direct solar illumination.

TABLE 2.—*Photometric measurements of the illumination of a horizontal surface by sun and sky light, with no clouds present, at Mount Weather, Va.*

[Foot-candles.]

Date.	Hour angle of the sun from the meridian.											
	6.0	5.0	4.0	3.0	2.0	1.0	0.0	1.0	2.0	3.0	4.0	5.0
1913.												
Sept. 23	.....	1,300	3,040	4,570	6,570	7,350	7,500	7,270	6,400	4,720	2,940	.....
24	.....	.....	2,400	4,140	5,880	6,640	6,810	6,680	6,120	4,330	2,860	.....
Oct. 4	.....	1,010	2,820	4,510	6,190	7,020	7,290	7,070	.....	.....	.....	.....
14	.....	.....	2,030	4,030	6,110	6,980	6,950	6,680	5,630	4,040	2,120	500
16	.....	.....	2,080	3,770	5,380	6,390	6,700	6,210	5,090	3,660	1,920	.....
Nov. 4	.....	.....	.....	.....	.....	.....	4,670	4,340	3,430	2,160	910	.....
5	.....	.....	1,330	3,080	4,370	5,380	5,630	5,280	4,450	3,150	1,500	.....
6	.....	.....	1,370	2,970	4,560	5,440	5,640	5,360	4,430	3,170	1,450	.....
7	.....	.....	.....	2,820	4,350	4,840	5,200	.....	.....	.....	.....	.....
12	.....	.....	1,350	2,210	3,750	4,920	5,250	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	3,350	4,200	4,590	4,300	.....	.....	.....	.....
Dec. 5	.....	.....	660	1,900	3,090	3,950	4,300	.....	.....	.....	.....	.....
9	.....	.....	.....	1,940	3,270	4,030	4,180	3,960	3,140	.....	.....	.....
12	.....	.....	650	1,930	3,150	3,990	4,320	.....	.....	.....	.....	.....
18	.....	.....	490	1,460	2,390	3,430	.....	.....	.....	.....	.....	.....
1914.												
Jan. 6	.....	.....	.....	.....	.....	.....	.....	3,890	3,220	1,980	680	.....
23	.....	.....	.....	1,460	2,390	3,210	3,610	3,500	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	3,880	4,460	4,430	3,580	2,200	960	.....
29	.....	.....	.....	2,330	3,570	4,550	4,720	4,420	.....	.....	.....	.....
Feb. 2	.....	.....	.....	.....	.....	.....	5,210	4,810	4,070	2,810	1,210	.....
9	.....	.....	.....	.....	.....	.....	5,280	4,980	4,050	2,680	1,370	.....
21	.....	.....	.....	.....	4,720	6,330	6,680	6,590	6,010	.....	.....	.....
24	.....	.....	.....	.....	.....	6,130	6,260	6,030	5,280	3,860	1,960	.....
May 1	770	2,460	4,280	6,150	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	2,570	4,150	6,340	7,770	8,280	8,390	.....	.....	.....	.....	.....
16	.....	.....	4,610	5,760	6,850	7,910	.....	.....	.....	.....	.....	.....
18	.....	.....	4,330	6,300	7,640	8,200	8,230	7,820	7,100	6,170	4,500	2,890
19	.....	.....	4,210	6,220	7,790	8,760	.....	.....	.....	.....	.....	.....
20	.....	2,000	3,540	5,420	7,360	7,590	7,380	6,690	5,920	5,110	3,200	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	7,150	5,890	4,160	.....
26	.....	.....	.....	5,920	6,200	6,430	6,560	6,530	6,300	.....	.....	.....
June 2	.....	.....	5,080	7,040	8,270	9,020	9,320	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	8,620	.....	.....	.....	.....	.....	.....
10	.....	.....	4,960	6,540	7,990	8,880	9,400	.....	.....	.....	.....	.....
12	.....	.....	.....	6,740	8,100	.....	.....	.....	.....	.....	.....	.....
24	.....	3,150	4,810	6,770	8,190	9,270	.....	.....	.....	.....	.....	.....
26	.....	.....	.....	5,900	8,050	.....	.....	.....	.....	.....	.....	.....
30	.....	3,540	5,350	6,830	9,090	9,900	10,000	9,720	9,060	7,520	5,500	3,210
July 22	1,350	3,250	5,410	6,720	8,470	9,510	.....	.....	.....	.....	.....	.....
29	.....	3,350	5,500	7,610	.....	.....	.....	.....	.....	.....	.....	.....
Aug. 7	.....	2,220	3,870	5,660	7,150	8,320	.....	.....	.....	.....	.....	.....
Sept. 10	.....	.....	.....	5,630	6,910	7,620	8,390	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	.....	7,180	5,850	3,680	2,240

TABLE 3.—*Photometric measurements of the illumination of a horizontal surface by sky light alone, with no clouds present, at Mount Weather, Va.*

[Foot-candles.]

Date.	Hour angle of the sun from the meridian.											
	6.0	5.0	4.0	3.0	2.0	1.0	0.0	1.0	2.0	3.0	4.0	5.0
1913.												
Sept. 23	.....	.....	785	904	951	988	1,139	1,191	1,173	1,112	.....	.....
24	.....	.....	.....	1,084	1,388	1,516	1,554	1,534	1,465	1,309	990	.....
Oct. 4	.....	577	965	1,126	1,180	1,200	1,200	.....	.....	.....	.....	.....
14	.....	.....	759	908	1,014	1,093	1,110	1,088	1,017	908	747	.....
16	.....	.....	788	970	1,109	1,193	1,214	1,207	1,142	1,012	823	.....
Nov. 4	.....	.....	.....	.....	.....	.....	1,514	1,476	1,340	1,093	686	.....
5	.....	.....	608	837	973	1,033	1,050	1,036	973	834	593	.....
6	.....	.....	684	778	855	903	920	890	840	740	570	.....
7	.....	.....	.....	756	944	1,266	1,452	.....	.....	.....	.....	.....
12	.....	.....	670	848	985	1,030	1,030	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	1,178	1,276	1,305	1,200	.....	.....	.....	.....
Dec. 5	.....	.....	435	645	753	938	1,100	.....	.....	.....	.....	.....
9	.....	.....	.....	739	855	928	940	900	808	.....	.....	.....
12	.....	.....	410	653	778	834	852	.....	.....	.....	.....	.....
18	.....	.....	372	815	1,075	1,216	.....	.....	.....	.....	.....	.....
1914.												
Jan. 6	.....	.....	.....	.....	.....	.....	.....	1,070	924	748	450	.....
23	.....	.....	.....	1,344	1,745	1,924	1,950	1,800	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	.....	1,277	1,250	1,144	905	580	.....
29	.....	.....	.....	780	955	994	1,072	1,080	.....	.....	.....	.....
Feb. 2	.....	.....	.....	.....	.....	.....	.....	760	760	690	508	.....
9	.....	.....	.....	.....	.....	.....	.....	900	878	772	540	.....
21	.....	.....	.....	.....	1,054	1,060	1,060	.....	.....	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	1,220	1,220	1,118	706	.....
May 1	642	1,400	1,800	2,158	.....	.....	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	2,318	2,568	2,728	2,868	.....	.....	.....	.....	.....
16	.....	.....	1,672	1,938	2,092	2,165	2,178	.....	.....	.....	.....	.....
18	.....	.....	1,475	1,740	1,875	1,935	1,934	1,885	1,784	1,612	1,370	1,050
19	.....	.....	1,875	2,028	2,470	2,933	.....	.....	.....	.....	.....	.....
20	.....	1,470	2,016	2,355	2,600	2,746	2,818	2,800	2,615	2,100	1,516	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	2,137	1,985	1,720	.....
26	.....	.....	.....	.....	2,800	2,600	2,500	2,600	2,770	.....	.....	.....
June 2	.....	.....	980	1,425	1,750	1,480	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	1,980	1,880	.....	.....	.....	.....	.....
10	.....	.....	1,185	1,210	1,360	1,720	2,000	.....	.....	.....	.....	.....
12	.....	.....	.....	1,190	1,220	.....	.....	.....	.....	.....	.....	.....
24	.....	830	960	1,080	1,200	1,330	.....	.....	.....	.....	.....	.....
26	.....	.....	.....	1,440	1,580	.....	.....	.....	.....	.....	.....	.....
30	.....	750	810	870	920	980	1,040	1,050	1,110	1,130	1,050	920
July 22	580	880	1,070	1,210	1,290	1,360	.....	.....	.....	.....	.....	.....
29	.....	750	870	970	.....	.....	.....	.....	.....	.....	.....	.....
Aug. 7	.....	1,390	1,900	2,160	2,410	2,750	.....	.....	.....	.....	.....	.....
Sept. 10	.....	.....	.....	780	790	800	820	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	890	800	710	640	.....

Comparison of Tables 2 and 3 shows marked variations in the ratio of sky-light illumination to the total illumination on a horizontal surface. In general, the ratio decreases as the sun approaches the zenith. In October and November, 1913, the sky illumination was about half the total when the sun was 10° to 11° above the horizon. On January 23, 1914, a very hazy day, it was more than half the total at noon, with the sun over 30° above the horizon. At noon on June 30, 1914, a very clear day, it was only one-tenth the total, while throughout May, 1914, an unusually hazy month, the noon ratio was about one-third.

If we divide the light intensities of Table 4 by the radiation intensity at normal incidence for the same days (2), we obtain the illuminating value of a calorie of solar heat energy for these days. This value is greater on clear days than on hazy days, and decreases in value with increased zenith distance of the sun. Thus, with the sun at zenith distance 48.3°, the average illuminating value of a calorie of solar radiation is 5,600 foot-candles; for solar zenith distance 66.5° it is 5,100 foot-candles, while for solar zenith distance 73.5° it is 4,600 foot-candles.

Similarly, comparisons of photometric measurements made on days when the sky was completely overcast with synchronous records by the Callendar pyrheliom-

eter of the heat energy received through the clouds, give 6,250 foot-candles per calorie as the average illuminating value of this diffuse radiation. Comparisons of the photometric readings of Table 3 with Callendar pyrheliometric records of the diffuse heat received from the clear sky, with the sun artificially eclipsed as explained above, give 8,900 foot-candles per calorie. These two latter values are subject to whatever error there may be in the reduction of the Callendar records to heat units (3).

The above comparisons indicate that radiation from an overcast sky is slightly richer in light rays, and radiation from a clear sky is markedly richer, than is direct solar radiation. They also show that the latter decreases in richness as the sun approaches the horizon, and also with a hazy sky. This is in accord with the researches by the Smithsonian Institution on atmospheric transmission of solar radiation of different wave-lengths (4).

TABLE 4.—*Solar illumination on a surface normal to the direction of the incident solar rays.*

[Foot candles.]

Date.	Zenith distance of the sun (degrees).									
	25.0	48.3	60.0	66.5	70.7	73.6	75.7	77.4	78.7	79.8
	Air mass.									
	1.1	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1913.										
Sept. 23 a.	.....	7,840	6,850	5,980	.....	.....	.....	.....	.....	.....
24 a.	.....	6,360	5,730	5,160	.....	.....	.....	.....	.....	.....
Oct. 4 a.	.....	8,040	6,850	6,020	5,380	4,890	4,470	4,110	3,780	3,480
14 a.	.....	8,710	7,360	6,240	5,270	4,470	.....	.....	.....	.....
16 a.	.....	8,040	6,740	5,660	4,490	3,570	.....	.....	.....	.....
Nov. 4 a.	.....	6,040	4,630	3,760	2,700	2,100	1,680	1,340	.....	.....
5 a.	.....	8,520	7,620	6,690	5,870	5,160	4,520	.....	.....	.....
5 p.	.....	.....	7,570	6,870	6,220	5,640	5,100	4,520	4,190	3,810
6 a.	.....	.....	7,770	6,760	5,890	5,120	4,460	3,880	.....	.....
6 p.	.....	.....	7,800	7,100	6,320	5,850	5,310	4,830	4,390	3,980
7 a.	.....	.....	7,320	6,500	5,760	.....	.....	.....	.....	.....
12 a.	.....	.....	7,140	5,930	5,100	4,570	4,300	3,940	.....	.....
21 a.	.....	.....	5,970	4,830	.....	.....	.....	.....	.....	.....
Dec. 5 a.	.....	.....	7,250	6,370	5,750	4,920	4,330	.....	.....	.....
9 a.	.....	.....	7,420	6,370	5,510	4,920	4,390	.....	.....	.....
9 p.	.....	.....	.....	6,460	.....	.....	.....	.....	.....	.....
12 a.	.....	.....	6,650	6,120	5,630	5,180	4,760	4,400	.....	.....
18 a.	.....	.....	.....	3,910	3,250	2,870	2,570	2,320	2,100	1,920
1914.										
Jan. 6 p.	.....	.....	.....	6,050	5,520	4,840	4,190	3,770	3,510	3,290
23 a.	.....	.....	3,200	1,610	762	.....	.....	.....	.....	.....
26 a.	.....	.....	6,270	4,960	4,270	3,820	3,450	3.140	.....	.....
29 a.	.....	.....	6,300	5,460	4,980	4,590	.....	.....	.....	.....
Feb. 2 p.	.....	.....	7,280	6,470	5,940	5,490	5.040	4,610	4,210	3,850
9 p.	.....	8,150	6,460	5,440	4,900	4,560	4,300	4,050	.....	.....
24 p.	.....	7,810	6,460	5,630	5,030	4,560	.....	.....	.....	.....
May 1 a.	.....	5,640	4,960	4,390	3,880	3,450	.....	.....	.....	.....
15 a.	6,940	5,160	.....	.....	.....	.....	.....	.....	.....	.....
16 a.	6,140	5,520	4,770	.....	.....	.....	.....	.....	.....	.....
18 a.	6,840	5,520	.....	.....	.....	.....	.....	.....	.....	.....
18 p.	.....	6,050	4,810	3,830	.....	.....	.....	.....	.....	.....
19 a.	6,180	5,180	.....	.....	.....	.....	.....	.....	.....	.....
20 a.	5,380	3,480	.....	.....	.....	.....	.....	.....	.....	.....
20 p.	.....	3,290	.....	.....	.....	.....	.....	.....	.....	.....
21 p.	6,030	5,020	.....	.....	.....	.....	.....	.....	.....	.....
26 a.	6,020	.....	.....	.....	.....	.....	.....	.....	.....	.....
June 2 a.	.....	7,210	.....	.....	.....	.....	.....	.....	.....	.....
3 a.	6,940	.....	.....	.....	.....	.....	.....	.....	.....	.....
10 a.	7,710	5,260	.....	.....	.....	.....	.....	.....	.....	.....
12 a.	8,180	7,000	.....	.....	.....	.....	.....	.....	.....	.....
24 a.	8,350	6,900	5,800	5,130	.....	.....	.....	.....	.....	.....
30 a.	9,700	8,250	.....	.....	.....	.....	.....	.....	.....	.....
30 p.	9,180	8,130	.....	.....	.....	.....	.....	.....	.....	.....
July 22 a.	8,870	7,710	6,530	5,610	4,860	4,260	3,790	.....	.....	.....
29 a.	.....	8,560	6,810	.....	.....	.....	.....	.....	.....	.....
Aug. 7 a.	6,230	4,230	3,340	2,630	2,100	.....	.....	.....	.....	.....
Sept. 10 a.	.....	8,100	.....	.....	.....	.....	.....	.....	.....	.....
15 p.	.....	8,630	7,710	6,830	5,970	5,160	.....	.....	.....	.....

TABLE 5.—*Photometric measurements of daylight and twilight illumination on a horizontal surface, at Mount Weather, Va.*

Nov. 4, 1913.[1]				Nov. 5, 1913.[2]				Nov. 6, 1913.[3]			
Sun's		Illumination.		Sun's		Illumination.		Sun's		Illumination.	
Hour angle.	Altitude.	Total.	Sky.	Hour angle.	Altitude.	Total.	Sky.	Hour angle.	Altitude.	Total.	Sky.
H. m.	*Deg.*	*Foot-candles.*		*H. m.*	*Deg.*	*Foot-candles.*		*H. m.*	*Deg.*	*Foot-candles.*	
0 03	35.7	4,670	.....	0 07	35.3	5,730	.....	0 05	35.0	5,580	.....
0 01	35.7	.....	1,520	0 04	35.4	.....	1,000	0 02	35.0	.....	932
1 24	32.2	.....	1,460	1 04	33.4	.....	994	1 05	32.9	.....	893
1 27	32.0	3,980	.....	1 08	33.1	5,170	.....	1 10	32.6	5,260	.....
1 41	30.8	3,620	.....	2 06	28.0	.....	963	2 05	22.8	.....	814
1 45	30.4	.....	1,345	2 10	27.6	4,370	.....	2 08	22.4	4,210	.....
3 09	20.0	.....	1,040	3 09	19.9	2,952	.....	3 05	20.2	2,960	.....
3 13	19.4	1,870	.....	3 12	19.4	.....	814	3 08	19.7	.....	751
3 58	12.4	971	.....	4 11	10.2	.....	521	4 07	10.4	1,270	.....
4 02	11.7	.....	663	4 14	9.5	1,110	.....	4 10	9.9	.....	524
4 16	9.3	.....	524	4 23	8.0	870	.....	4 23	7.6	.....	463
4 22	8.8	561	.....	4 26	7.3	.....	453	4 25	7.3	807	.....
.....	.....	.....	.....	4 35	5.8	609	.....	4 36	5.4	573	.....
.....	.....	.....	.....	4 49	3.3	318	.....	4 37	5.2	.....	347
.....	.....	.....	.....	4 53	2.6	242	.....	4 49	3.1	.....	279
5 05	0.6	90	.....	5 00	1.3	170	.....	4 58	1.5	.....	172
.....	.....	.....	.....	.....	.....	.....	.....	5 06	0.0	.....	98
[4] 5 08.5	0.0	.....	.....	[4] 5 07.4	0.0	.....	.....	[4] 5 06.2	0.0	.....	.....
.....	.....	.....	.....	[5] 5 11	− 0.6	.....	.....	[5] 5 10	− 0.7	.....	.....
5 12	− 0.6	.....	37	5 15	− 1.4	.....	57	5 17	− 2.0	.....	27
5 20	− 1.9	.....	13	5 23	− 2.9	.....	14	5 29	− 4.2	.....	3
.....	.....	.....	.....	.....	.....	.....	.....	5 38	− 5.9	.....	0.4

[1] Nov. 4. A few Fr. Cu. at noon. No clouds recorded during afternoon, but haze was dense, and sun disappeared in bank of haze.
[2] Nov. 5. No clouds. Brilliant sunset. Yellow sky with pink glow above, followed by dull red. Sky bright red on horizon at 6:19 p. m. Distinguishable at 6:28 p. m., but had disappeared at 6:32 p. m. (apparent time).
[3] Nov. 6. No clouds. Brilliant sunset; yellow, followed by pink and red.
[4] Computed time of sunset.
[5] Observed time of sunset.

Photometric measurements show that with a completely overcast sky the illumination on a hori ontal surface may be half as great as with a clear sky, and that not infrequently it is one-third as great. From the factor 6,250 derived above, in connection with the Callendar records of radiation on a horizontal surface, illumination intensities of only 168 foot-candles are obtained at noon in winter with a dense fog prevailing, and of only 85 foot-candles at noon in midsummer, during a severe thunderstorm.

In Table 5 are given photometric measurements on three afternoons in November, 1913, that were continued until after sunset. The computed time of sunset is for the center of the sun's disk and for the true horizon. The observed time is the time at which the upper limb of the sun actually disappeared behind distant hills that were somewhat below the horizon of Mount Weather. It will be noted that on November 5 and 6, both of which were days with clear skies and brilliant sunsets, the readings are in good accord. On the 4th, however, which was a hazy day, not only was the daylight illumination lower, but the twilight illumination also diminished much more rapidly with increased distance of the sun below the horizon.

With the discontinuance of solar radiation work at Mount Weather at the end of September, 1914, the Sharp-Millar photometer was sent to Salt Lake City, Utah, where daylight illumination measurements are being made under the smoke cloud, covering the center of the city, and also at a point in the suburbs that is comparatively free from smoke.

SUMMARY.

Photometric measurements made at Mount Weather, Va., show that with a clear sky the total midday illumination on a horizontal surface varied from 10,000 foot-

candles in June to 3,600 foot-candles in January. It is less than the direct solar illumination on a normal surface from September to February, inclusive, but exceeds the latter from May to August, inclusive, for a period of from four to eight hours in the middle of the day.

The illumination on a horizontal surface from a completely overcast sky may be half as great as the total illumination with a clear sky, and is frequently one-third as great. On the other hand, during severe thunderstorms at noon in midsummer, the illumination may be reduced to less than one per cent of the illunimation with a clear sky.

The ratio of sky-light illumination to total illumination on a horizontal surface at noon in midsummer varies from one-third to one-tenth. In midwinter it varies from one-half to one-fifth.

When the sky is clear the twilight illumination on a horizontal surface falls to 1 foot-candle about half an hour after sunset, or when the sun is about 6° below the horizon.

REFERENCES.

(1) **Sharp, Clayton H. & Millar, Preston S.** A new universal photometer. Electrician, 1908, **60**:562–565.
(2) *See* Bulletin of the Mount Weather Observatory, 1913, v. **6**, pt. 5, p. 218–219; and MONTHLY WEATHER REVIEW, March, June, and September, 1914, **42**:139, 310 and 520.
(3) MONTHLY WEATHER REVIEW, August, 1914, **42**:480.
(4) Annals of the Astrophysical Observatory of the Smithsonian Institution, Washington, 1913, **3**:135–138.
Smithsonian Physical Tables, 6th ed., 1914, p. 182.

HEAT FROM THE STARS.[1]

In the MONTHLY WEATHER REVIEW for June, 1914 (p. 347), were presented some figures expressing the amount of heating at the earth's surface which may properly be attributed to the radiation received from the planets of the solar system. Equally interesting is the similar question concerning the stars, those innumerable suns lying far beyond our own prime source of heat and energy. Among others Dr. W. W. Coblentz has attacked this problem, and first by constructing an exceedingly delicate radiometer. His instrument is essentially a bismuth–platinum, or a bismuth–bismuth plus tin alloy thermocouple exposed in a high vacuum. He has measured the radiation from 105 stars, among other celestial objects, and finds "that red stars emit from two to three times as much total radiation as blue stars of the same photometric magnitude."

Measurements were made on the transmission of the radiations from stars and planets through an absorption cell of water. By this means it was shown that, of the total radiation emitted, the blue stars have about two times as much radiation as the yellow stars, and about three times as much radiation as the red stars, in the spectral region to which the eye is sensitive. * * *

Measurements were made to determine the amount of stellar radiation falling upon 1 square centimeter of the earth's surface. It was found that the quantity is so small that it would require the radiations from Polaris falling upon 1 square centimeter to be absorbed and conserved continuously for a period of one million years in order to raise the temperature of 1 gram of water 1° C. If the total radiation from all the stars falling upon 1 square centimeter were thus collected and conserved it would require from 100 to 200 years to raise the temperature of 1 gram of water 1° C. In marked contrast with this value, the solar rays can produce the same effect in about one minute.

[1] **Coblentz, W. W.** A comparison of stellar radiometers and radiometric measurements on 110 stars. *Abstract in* Jour., Washington ac. sci., Washington, Jan. 19, 1915, 5: 33–34. Detailed paper will appear in the Bulletin of the U. S. Bureau of Standards.

E. KRON ON THE EXTINCTION OF LIGHT IN THE TERRESTRIAL ATMOSPHERE IN THE REGION OF THE ULTRA-VIOLET.[1]

By WILHELM SCHMIDT.

Kron's report deals with photographic-photometric observations, by means of a quartz spectrograph, on the brightness (Helligkeit) of the sun at the Astrophysical Observatory at Potsdam, Germany, during the years 1911 to 1913. The extraordinary range [Abstufungsmöglichkeit] permitted by the conditions of the experiments enabled the region of accurate measurements to include both the extraordinary differences in intensity in the different spectral regions (between wave-lengths 430$\mu\mu$ and 310$\mu\mu$) and the total solar intensity as related to its altitude above the horizon (measurements being possible down close to it). There is nothing new in the methods of computation which are based upon the Bouguer Formula and Bemporad's values for the air masses.

In general it appears that the coefficient of transmission p is subject to variations from day to day, while the observations for the same day show good agreement among themselves with departures due to increased absorption for the lowest solar altitudes as would be expected if masses of vapor occur. The mean values obtained by Kron are in part essentially lower than those secured in 1909 and 1910 by C. G. Abbot[2] on Mount Whitney; as the following comparison shows. The third column of values have been reduced to Potsdam barometric conditions by multiplying.

Values for the coefficient of atmospheric transmission, p, *by Kron (Potsdam) and Abbot (reduced to Potsdam).*

Wave length. λ	Kron's value for p.	Abbot's value for p (reduced).
μ		
0.432	0.648	0.762
.390	.531	.678
.371	.464	.629
.341	.354	.531
.325	.268	.457

Since only the last of the Abbot values seems to have been increased by the action of diffused light in his instrument, it is at least evident that values determined for a high-level station can by no means be directly reduced to low-lying stations.

Rayleigh is the authority for the assumption that it is particularly the absorption in the region of the shortest wave-lengths (except certain bands, e. g. those due to ozone, below 0.325μ), which is produced by scattering from air molecules so that its amount is inversely proportional to the fourth power of the wave-length, λ. If one computes from Kron's observations the absorption-coefficients $C = \log \text{nat } p$, then they may be readily represented by a formula of the form

$$C = \frac{\alpha}{\lambda^4} + \beta,$$

where $\alpha = 0.01325$ and $\beta = 0.066$. The small value of β at once shows the formula closely in agreement with the above law, while this agreement is yet further improved

[1] A translation of a review in Met. Ztschr., Braunschweig, November, 1914, **31**: 555–6.—C. A. jr.
[2] Annals of the Astrophysical Observatory of the Smithsonian Institution, vol. 3, Washington, 1914.

if one assumes that β expresses the absorption due to foreign constituents of the air which may be responsible for the day-to-day variations.

Now it is possible to demonstrate that Rayleigh's law holds good for these foreign constituents also, that they also function by molecular diffraction. Water vapor is the first to occur to us in this connection, and for this element F. E. Fowle [3] has already devised a formula similar to that previously suggested. Employing his figures and expressing the amount of the water vapor w in centimeters of the equivalent precipitated water, then $\alpha = 0.00889 + 0.00067w$, $\beta = 0.011w$, and these well represent the observations, particularly the general mean of all, with the exception of very slight variations.

Kron summarizes his results as follows:

The extinction in the region of the ultra-violet up to 0.325μ may be wholly explained by molecular diffraction, together with the absorption by water vapor which is itself chiefly due to molecular refraction as found by Fowle.

Beyond the wave-length 0.325μ his observations reveal an increase in the extinction which is probably due to the influence of the ozone band here beginning to make itself felt.

[3] Astrophysical journal, 1913, **38**: 392; Meteorol. Ztschr., 1914, **31**: 270. Monthly Weather Review.

SECTION II.—GENERAL METEOROLOGY.

PRESENT STATUS OF OUR KNOWLEDGE OF THE CAUSES OF THE DIURNAL CHANGES IN TEMPERATURE, PRESSURE, AND WIND.

(Communicated to the International Meteorological Congress at Chicago, August, 1893.)[1]

By Prof. Dr. J. M. PERNTER.

[Dated University, Innsbruck, Austria-Hungary, May 5, 1893.]

[At the time of this paper the author, born March 15, 1848, at Neumarkt, Tyrol, was extraordinary professor, but in October, 1893, he was appointed regular professor of cosmical physics at the University of Innsbruck. He remained there, giving brilliant service, until October 1, 1897, when he was appointed professor of terrestrial physics at the University of Vienna and director of the Imperial Central Institute for Meteorology and Terrestrial Magnetism. This institute he greatly enlarged both in size and scope of service, and his exertions there contributed to the causes of his relatively early death at Arco in southern Tyrol December 20, 1908.—C. A. jr.]

The regular daily oscillations that we are accustomed to speak of as periodical are at present known so accurately in reference to the facts themselves that with great confidence we can say that further investigation will not reveal to us anything of importance that is new. Especially has the periodic diurnal variation of temperature and pressure for all regions of the globe in all latitudes and in the most diverse altitudes above sea level, been presented in such detail that even in the minutiæ of the diurnal rate there can scarcely be anything more discovered. This is certainly less true of the winds, but even as to this element important recent discoveries leave nothing more to be expected. It is not now my problem to collect the facts relative to the rate, the diurnal periodic oscillation of temperature of pressure and of the wind; but rather it is my duty to present the present condition of the theoretical explanations of these phenomena. Therefore I assume that in general we already know both the general course and the details of the diurnal variation of the elements under consideration.

I. EXPLANATION OF THE DAILY TEMPERATURE MARCH.

Under the word temperature in general we in meteorology understand the temperature of the air, and under this last expression, if not otherwise expressly stated, we mean the temperature of a stratum of air at about 1 meter above the earth's surface.

We must also state by way of prelude what we understand to be an explanation of a phenomenon. We can say a phenomenon is explained only when we are in a position to give its physical cause; it is perfectly explained only when we can bring this cause into such a mathematical expression that with the help of the latter we are in a position to compute the phenomenon itself.

We recognize with perfect clearness the two very different causes that give the curve of diurnal march of temperature its peculiar form. During each diurnal rotation of the earth the sun is above the horizon so long as it is describing its daylight path, and therefore the heat that is received at any instant is proportional to the sine of the altitude of the sun. Therefore during the daytime the curve of temperature is represented by a sine curve or wave. After sunset the influence of the sun disappears and from the end of the evening twilight to the beginning of the morning twilight it is equal to zero. During the nocturnal path of the sun [terrestrial] radiation only is effective, and this part of the curve of daily temperature march will be, in accordance with the law of terrestrial radiation, an exponential or logarithmic line. The appearance of the curve allows us to easily recognize these two branches; from sunrise to sunset the first branch presents clearly the wavelike elevation of a sine curve; from sunset to sunrise the second branch of the curve steadily descends in the well-marked form of an exponential curve attaining the lowest point at about the time of sunrise. There are, therefore, two causes that determine the diurnal march of temperature, viz, the radiation outward from the earth and the radiation earthward from the sun. So long as the radiation from the sun is effective during the day, it alone determines the form of the curve of temperature, inasmuch as it far overpowers the radiation from the earth which is always present, whereas the latter is the only cause determining the form of the curve during the nighttime.

We therefore know the physical causes of the periodic diurnal changes of temperature and are thus justified in saying that we are able to explain this phenomena.

But there is now a further question whether this knowledge also puts us in a position to give a mathematical expression which enables us to compute adequately the phenomenon and one that can in every case be introduced as the analytical equivalent of the diurnal curve.

In this respect we must at once confess that we are not in a position to formulate a mathematical expression that shall represent the whole curve, both the day branch and the night branch, by means of one formula. But a different answer will be given if we treat the two branches separately, since we are able to give a mathematical expression for the night branch that satisfies the demands of a physical formula, that is to say one in which well-defined physical quantities are utilized.

Lambert (1) was the first who subjected the two branches of the temperature curve to separate treatments. For the night branch he proposed an expression that represented the exponential and is of the same form as we employ to-day. A physical deduction of this expression was first attempted by Weilenmann (2); but he made untenable assumptions in that he referred the whole nocturnal cooling of the air to the cooling of the earth's surface by radiation toward the atmosphere and further assumed that the cooling of the lowest stratum of air was only due to the giving of its heat down to the cooled earth. Maurer (3) then showed that the thermal conductivity of the air did not come into consideration and that the air itself cools directly by reason of its own radiation. On this basis he deduced the formula for the nocturnal temperature march and comes to the same expression that Weilenmann attained notwithstanding his false assumptions, viz,

$$T = T_0 + cb^z$$

[1] The publication of this memoir has been delayed for the reasons given in the MONTHLY WEATHER REVIEW, February, 1914, 42 :93.

In this equation z represents the time and b is equivalent to $e^{\frac{\sigma}{\rho c}}$. Thus Maurer gave for b an expression that was physically intelligible in which σ represents the coefficient of radiation of the air, ρ the density of the air, and c its specific heat.

Weilenmann had found that b is a constant for all places and all times. But Maurer objected to this. He made σ refer to the unit of volume and therefore according to his formula b must vary with the density. On the other hand Trabert (4) has shown that the coefficient of radiation is independent of the density and must therefore refer to the unit of mass, viz, that the expression $\frac{\sigma}{\rho}$ used by Maurer represents the constant coefficient of radiation of the air. Hence, b must be a constant for all places and all times unless perhaps the coefficient of radiation of the air depends upon the temperature. But Trabert has shown that the latter case is highly improbable. On the average

$$\log b = -0.066.$$

If now we represent the coefficient of radiation of the air for a unit mass, or one gramme, by σ then from $b = e^{-\frac{\sigma}{c}}$ we obtain for σ the following value:

$$\sigma = -0.547 \log b$$
$$= 0.036 \text{ calories per hour.}$$

On the other hand with regard to T_0, which should represent the temperature of that ideal envelope which we conceive to replace the radiation from all surrounding bodies, Trabert finds from the average of 42 stations distributed over the whole earth that it depends on the average temperature, as follows:

$$t_0 = -3.4° + 1.003 t_m$$

where t_0 and t_m express the values of T_0 and T_m in centigrade degrees.

We have thus obtained for the nocturnal branch of the diurnal temperature curve, a mathematical expression derived from physical causes and in which we understand the physical quantities that occur therein. The formula $T = T_0 + Cb^z$, in which z represents the time expressed in hours after sunset, justifies us in the belief that we can completely explain the nocturnal branch of the temperature curve.

Unfortunately we do not succeed so well in our attempt to explain the daylight branch of the curve of diurnal periodic temperature variation. In order to find a mathematical expression that shall be physically intelligible we must start with the solar radiation as the cause of this branch of the curve. The intensity of the solar radiation after its passage through the atmosphere and for the solar altitude h is expressed by

$$I = Ap^{\varepsilon} \sin h$$

and this is the quantity of heat that falls upon the horizontal ground. Now all thermal influences during the daytime in so far as they all depend upon the solar radiation are proportional to this quantity. Among these may be enumerated:

(1) The warming of the air by its absorption of direct solar rays.

(2) The warming by absorption of the rays reflected from the earth.

(3) The warming by absorption of solar rays scattered in and through the atmosphere.

(4) The convection of heat from the ground warmed by the solar rays.

Further we have to recall the negative influences—

(5) The cooling by radiation outward which again is proportional to the temperature of the air.

(6) The cooling by the evaporation of water, which latter again is proportional to the warming by the sun.

The introduction of all these factors into the analytical expression for the daytime temperature march is impracticable for many reasons. Even the coefficient of transmission, p, is variable in a manner too little understood by us to enable us to introduce it correctly; and the other enumerated factors are understood far too little to enable us to express them in mathematical symbols. In consideration of these difficulties to the presentation of a physically intelligible mathematical expression for the daylight branch of the diurnal temperature march, Lambert (5) said long since: "We shall accomplish much if, without too notable error, it can be assumed that the heat which the earth actually receives from the sun is at least proportional to that which the earth could receive if there were no obstacles." To be sure, we know to-day that the latter is the case, but neither this nor the great progress of our knowledge makes the representation of the desired formula any easier.

We can therefore pass over the attempts that have been made in this direction by Lambert himself (6), by Lamont (7), and by Weilenmann (8). However, with reference to the attempt made by Weilenmann it may be said that it appears interesting because his final formula endeavors to present in one expression the whole curve, with its day branch and its night branch. All these formulas, however, give no deep insight into the processes by which Nature determines the periodic temperature change, such as it is desired to obtain from a mathematical expression deduced from the physical causes of the phenomenon. Indeed we fear that these formulas do not contribute to the explanation and the intelligibility of the temperature curve any more than would an ordinary series such as, in the absence of any physical laws, we ordinarily use for presenting any given phenomena.

In fact, Angot (9), leaving aside every theoretical formula, has applied Bessel's Series for the presentation of the diurnal rate of temperature during the daylight hours. Since the form of the daylight branch of the temperature curve suggests a sine wave, and since the formula for the intensity of the rays $I = Ap^{\varepsilon}\sin h$ makes it clear that we have to deal with a phenomenon that is approximately proportional to the sine of the altitude of the sun. Therefore among all the series that we could use for the empirical presentation of this daylight branch, evidently the sine series is the most appropriate. If the time of the maximum air temperature coincided with the maximum altitude of the sun, then certainly an empirical formula in terms of the sine of the simple hour-angle of the sun would abundantly suffice to represent the phenomenon. But since the dependence of the curve on the altitude of the sun is not so simple as all this, therefore we must apply many terms of the sine series, such as twice, three times, etc., the hour angle. Angot found, however, that in order to present the daytime formula only, it was sufficient to

utilize only terms with twice the hour angle, and with this we obtain a very approximate presentation of the daytime branch of the temperature curve.

We must thus recognize that in regard to the complete explanation of the daytime branch of the temperature curve we are not so fortunate as we have been with the nocturnal branch.

In many cases, especially when it is desired to introduce the temperature rates into a computation, it is necessary to have a formula that brings the curve of temperature for the whole day of 24 hours into one expression. It is evident that we have much less hope of presenting a theoretical expression based on the recognized physical causes for the whole day, than we have for the daylight branch alone. Weilenmann's above-mentioned attempt to do this must certainly be regarded as unsuccessful and a second attempt has never been made. Therefore, in order to meet the above-mentioned need, we must again take refuge in a series, and a series employing the fewest terms possible for an accurate presentation of the phenomenon. Thus we are again thrown back upon the sine series. The complete sine wave consists of a crest and a trough, hence there is a maximum and a minimum. Now in the regular simple sine wave, the maximum and the minimum are equally distant from the zero value that lies between them, but by superpositions of waves having ½-wave-length, ¼-wave-length, etc., of the original simple wave-length, and further by having different initial times one may so shift the maximum and minimum as to reproduce those actually presented by the diurnal curve of temperature. If, therefore, one employs a sufficient number of the terms of the Bessel Series to represent the curve of the daily temperature march it will be possible to represent the phenomenon exactly. Wild (10) has shown that usually one must go even further than four times the angle to secure sufficient accuracy. In many cases, and especially where the expression for the daily march of temperature is to be introduced in computations, it suffices to take such a number of terms of the Bessel series as will reproduce the general form of the temperature curve. Usually one stops with the term depending upon the 2-fold angle, but I can not refrain from saying that to me this always seems to be too small a number of terms for the proper presentation of the complete diurnal curve. If we do not introduce the 3-fold angle, the form of the curve given by the formula departs too much from the actual curve. In most cases, however, this departure need not be of much importance.

But no matter how many terms of the Bessel formula we introduce, whether we stop at the 2-, 3-, or 4-fold angle, one should never forget that *in nature the daily curve of temperature is not attained by a superposition of these different waves*, the latter are only a mathematical substitute in order to attain by computation to the same curve that Nature has produced in an entirely different manner. We know with certainty how this peculiar curve is produced in nature: During the daytime the sun, or Nature, produces a simple sine curve, but only the upper half of the wave; during the nighttime, however, radiation produces the continuation of the curve and draws a logarithmic line. Only the maximum, therefore, belongs to a wave of the sine-curve type, the minimum has nothing whatever to do with such a wave. If, however, we determine to construct the whole curve out of sine-waves the latter is only a mathematical device and we should never forget that it is so.

I have thought that this exposition should be given because this seems to me to be the correct physical conception of a question that is, moreover, worthy of a fundamental discussion. I will now summarize the present condition of our knowledge of the explanation of the diurnal periodic variation in temperature in the following paragraphs:

(1) We know that the curve of this variation consists of two entirely distinct parts, the daylight and the nocturnal branch.

(2) We know the physical causes that give to each of these branches their peculiar form. The daylight branch is due to the radiation from the sun, the variable warming depending on the sine of the sun's altitude. The nocturnal branch owes its form to the cooling by radiation from the earth. Therefore the former is the crest of a sine-curve and the latter is the steady fall of a logarithmic line.

(3) We are enabled to represent the nocturnal branch by a mathematical formula deduced from theoretical considerations on the basis of well-known physical causes.

(4) We are not also in a position to deduce such a formula for the daylight branch and must therefore seek to represent it for computational purposes by means of the sine curve, i. e., by Bessel's series, of which Angot finds that, even for the daylight branch, it is sufficient to include only the 2-fold angle.

(5) Still less do we possess a physically established theoretical formula to represent the whole diurnal curve. We can, however, in the absence of such a formula (which would give one maximum and one minimum only) again take refuge in Bessel's series, but now in order to attain an accurate representation of the true curve, we must utilize a development to at least the 4-fold angle.

II. EXPLANATION OF THE DIURNAL RATE OF PRESSURE.

As the temperature curve of the diurnal change is characterized by one maximum and one minimum, so the most prominent character of the diurnal curve of pressure is the twofold maximum and the twofold minimum. In the temperate zone there occurs also a very small third maximum, but as this is not general it can not be reckoned as a general property of the pressure curve. The knowledge of the course of these phenomena is to-day as perfect as can be desired (11). But to the question what are the physical causes of the diurnal change of pressure, we are not yet in position to give any satisfactory answer. In comparison with the answer that we can give relative to the diurnal curve of temperature, we can say very little as to the daily pressure march. In this case we know not the physical causes that determine this march, and still less do we know the laws in accordance with which we should devise a theoretical mathematical formula based on physical causes, in order to represent the phenomenon itself. Hence this part of my problem must be very quickly answered by admitting that we do not know the physical causes of the diurnal change of pressure, and therefore also have no mathematical expression that satisfies the requirements of a physically intelligible formula.

But in this way I should but illy present the present condition of the question. Since the discovery of the barometer there has been scarcely a single prominent meteorologist but has interested himself in the solution of this problem. Therefore in order to present the present condition of our knowledge on the subject, I must at least

collect the hypotheses, whether good or bad, that do not embody anything preposterous and that have found either general or limited acceptance.

Of all those explanations that have been thus far suggested, Dove's theory (12) on the pressure of the dry air is the only one that has been given up.

With one single exception, all assume as the basis of the diurnal curve of air pressure, the diurnal changes in temperature. Ramond (13) has applied this latter phenomenon in the simplest manner to the explanation of the diurnal variation of pressure. He assumes that the heating of the atmosphere by the sun, makes itself felt for the meridians that lie between 9 a. m. and 3 p. m. Over this whole region the atmosphere expands and overflows toward the west and the east, whereby the minimum of the afternoon and the two maxima, morning and evening, are explained. In order to explain the nocturnal minimum, Ramond assumes that there is an increase of temperature about midnight.

Espy (14), in order to explain the principal maximum of 10 a. m., introduced a new cause, viz, the tension imparted to the lower stratum of warmed air, since although warmed it can not immediately expand. With reference to the nocturnal minimum, Espy is still more unfortunate than Ramond. Kreil (15) retained Espy's idea and added a further active cause in the shape of ascending and descending currents of air to explain our phenomenon. The first maximum he explained according to Espy, the afternoon minimum according to Ramond and with the help of the ascending currents, while the evening maximum was cited as a consequence of the descending current. His explanation of the nocturnal minimum was interesting. The lower strata, compressed in consequence of the descending current, must expand on the cessation of this current, and thus again there arises an ascending but very weak current that leads to the nocturnal minimum.

The Espy theory of tension was opposed by Lamont (16), but Blanford (17) and Angot (18) later defended it.

Rykatchev (19) gave a very different explanation. He made the diurnal variation of the pressure depend upon the regular diurnal changes in both the upper and the lower air currents. He put the increase and decrease of the atmospheric pressure proportional to the difference of the velocity of the transportation of the air per unit of longitude, and then by the summation of the effect of the upper and the lower currents of air he comes to his explanation of the diurnal variation of pressure. Where the velocity of the wind increases as it advances, it evidently leaves thinner air behind it; where with increase of progress it diminishes its velocity it produces a damming up or accumulation and increases the density of the air. The summation of these effects of the upper and the lower currents of air is complicated and rather forced. Rykatchev describes the process, as he understands it, quite fully and explains in detail how according to his views the two maxima and two minima must be developed.

Liais (20) also brings in a new idea to explain our phenomenon. He points out the fact that the air ascending in the locality where it is most strongly heated, must remain behind toward the west in consequence of the inertia of its ascent, and thus contributes to the formation of the forenoon maximum. On the other hand, in the late afternoon and early hours of evening, the descending air must flow forward toward the east, and thus exert a pressure that contributes to the formation of the evening maximum. In other respects Liais must be considered as the predecessor of Rykatchev, since with the help of the just mentioned item he attempted to explain the diurnal march of pressure by reason of the horizontal air currents due to the warming.

If we now add the remark that since the time of Dove the diurnal increase and decrease of vapor pressure also has usually been adduced in explanation of the increase and diminution of atmospheric pressure, we may say that we have spoken of all the physical causes that have been used to explain the diurnal change of pressure. Only one quite isolated attempted explanation still remains to be mentioned.

Peltier (21) believed that the electric condition influenced the pressure of the air. The earth is negatively electrified; the vapors that rise from the earth are also negatively charged. At the time of the most rapid evaporation the electric repulsion is also the greatest; the barometer falls. But when the vapors attain higher altitudes they become positive toward the earth, and there results an attraction; the barometer rises. If in consequence of cooling, a condensation of vapor occurs in the lower stratum then the barometer falls; if the cooling proceed further and eventually the upper strata sink lower, then the barometer must again rise.

According to all this, we can certainly not say that too little has been done to discover the physical causes of the diurnal change of pressure; in fact, there is not a single cause at work in the atmosphere or acting upon it that has not been seized upon. We have taken these causes individually, combined and accumulative, and must confess that in fact there has been no want of effort to attain the object desired; and still all these efforts at explanation remain unsatisfactory. There is not a single one of them of which the majority of meteorologists would say that it suffices; not one of these solutions is of such a kind that it gives us confidence that the correct solution has been found or indeed that the true cause of the phenomenon even as to its principal cause has been found. We have only found that the temperature is one of the principal factors. We find only that most of the adduced causes may contribute many details to the actual form of the diurnal curve of pressure; the fundamental cause, properly so called, we must state has not yet been recognized. If the recognition of the fundamental causes of the diurnal change in pressure seems so unsatisfactory, on the other hand, in reference to a theoretical formula deduced mathematically from the physical causes to represent this diurnal curve of pressure, no attempt has been made. Those who have presented the above attempted explanations are satisfied to describe verbally the influence of their assumed causes without computing, even approximately, the magnitude of the effects to be expected.

Under such circumstances one need not be surprised that it was preferred to give first a more accurate and analytical description of the diurnal curve of pressure for the whole globe, in order thereby when possible to secure a better basis for a mathematico-physical theory of the phenomena as Hann (22) has expressly stated. The process to be chosen is given by the curve of diurnal pressure. In the most regular form of this curve as it occurs in the Tropics and also in the annual averages for the temperate zones, having two maxima 12 hours apart and two minima also 12 hours apart, it points so clearly to

the double sine curve that we are involuntarily led to its mathematical presentation by means of the Bessellian sine series.

It is to be expected, considering the nature of the curve, that the term depending on the 2-fold angle must be the most important and that the whole phenomenon will find its basis therein, whereas disturbing influences will be shown by the other terms.

Lamont (23) has already adopted this method of mathematical description. Of course, some had already used this method of presentation of the diurnal pressure curve by means of the Bessel series. Lamont, however, limits himself to the terms of the single and 2-fold angle and is only able to show that the amplitudes of the 2-fold waves are of remarkable magnitude and depend only on the geographic latitude, as also that the epochs of these double waves is the same over the whole earth and agrees with the times of maximum and minimum and coincides with the times of maxima and minima as read directly from the diurnal curve of pressure. On the other hand he shows that the term with the simple angle is the more variable. The term with the 2-fold angle shows itself independent of temperature, cloudiness, rainfall, and other local influences all of which occur plainly in the first term. Hence he calls the double wave the "atmospheric flood and ebb," but, of course, excludes from this conception all influences of gravitation. Still he could find no other explanation of the great regularity and the independence of terrestrial processes of this double wave except that it is ascribed to a cosmic force which he preliminarily would call an "electric" force. In his studies of this subject Lamont had only a very limited number of stations at his disposal.

Hann (24) and Angot (25) have helped us in this respect, for in their investigations they have taken into consideration many more than a hundred stations distributed over the whole earth. They completely confirm Lamont's results and even give them greater precision. Hann represents the amplitude of the double wave, in its dependence on the latitude, by the following equation:

$$a_2 = -0.222 + 1.184 \cos^2\phi$$

with regard to which he remarks that slight irregularities are still to be seen therein. Lamont also had pointed out such small irregularities in the double wave. Angot has sought to eliminate these irregularities under the conviction that the term depending on the 2-fold angle does not depend on any terrestrial accident. He holds that the influence of temperature as expressed in the term depending on the simple angle is, strictly speaking, expressible only by a series of several terms (as is certainly not to be doubted); therefore the term depending on the 2-fold angle is a complex one that consists of a double wave of pressure independent of temperature, with superposed terms depending on the 2-fold angle of the temperature. He separates these two numerically and retains the purely constant term of the double wave of pressure. Of course this can not be done without being arbitrary to a certain extent. Following La Place's presentation of an ebb and flow, he expresses the amplitude of this principal wave of pressure (onde semidiurne principale) by the formula:

$$a_2' = \frac{A \cos^2\delta}{r^3}$$

where δ is the declination of the sun, r is the radius of the earth's orbit. He then determines A, the amplitude, from the observations and finds the expression:

$$A = 0.926 \frac{b}{760} \cos^4\phi$$

where ϕ is the latitude and b is the average pressure of the air. He thus arrives at the following expression for the "semidiurnal principal wave" of atmospheric pressure:

$$y = 0.926 \frac{b}{760} \cdot \frac{\cos^2\delta}{r^3} \cdot \cos^4\phi(2x + 64°).$$

This latter would therefore be the expression for the constant double wave of pressure resulting from a "cosmic cause."

We must recognize that by these investigations of Hann and Angot our knowledge of the phenomenon of the variation of pressure has been advanced to an extraordinary extent. We now know with certainty that the double wave of pressure is a constant phenomenon, so constant that we think only a cosmic cause can offer a satisfactory explanation thereof. The causes that can enter as disturbances occur in the remaining terms of the sine series. Nevertheless we must recognize the fact that a physical explanation of the phenomenon has not yet been found. In order that it may be found it will be necessary on the one hand that we state the "cosmic cause" in order that when possible we may deduce from it a mathematical expression that shall represent the phenomena. Equally do we now know that temperature, cloudiness, rainfall, and local influences do have disturbing influences on the course of the principal wave, but we have as yet no expression deduced from their physical properties that formulates the effect of these disturbing influences. Therefore we can not to-day speak of a physical explanation of the daily range of temperature.

Quite recently [1890] Margules (26) made the only attempt known to me relative to such an explanation. He develops mathematically the idea of Sir William Thomson (27), now known as Lord Kelvin. Sir William [2] says:

> The explanation probably is to be found by considering the oscillations of the atmosphere, as a whole, in the light of the very formulas which Laplace gave in his Mécanique Celeste for the ocean, and which he showed to be also applicable to the atmosphere. When thermal influence is substituted for gravitational, in the tide-generating force reckoned for, and when the modes of oscillation corresponding respectively to the diurnal and semidiurnal terms of the thermal influence are investigated, it will probably be found that the period of free oscillation of the former agrees much less nearly with 24 hours than does that of the latter with 12 hours; and that therefore, with comparatively small magnitudes of the tide-generating force, the resulting tide is greater in the semidiurnal term than in the diurnal.

Margules carried out the computation and found Thomson's prediction justified. This temperature-wave progressing from meridian to meridian successively in a rotating spherical shell which is considered similar to the atmosphere, has a whole-day period of the form

$$\tau = C \sin\omega \sin(nt + \lambda),$$

where τ is the temperature, ω the polar distance, λ the geographic longitude, n the rate of rotation of the earth, t the time. It produces for the temperature $T_0 = 273°$ a pressure-wave having the form

$$\varepsilon = C \sin(nt + \lambda)[1.146 \sin\omega - 0.423 \sin^3\omega - 0.370 \sin^5\omega - \ldots]$$

[2] As the original English seems to have passed through a series of translations, the Editor takes the liberty of reprinting the original words of Kelvin on page 400 of the Proceedings of the Royal Society of Edinburgh, Vol. XI.

On the other hand, temperature-waves having a ½-day period and the shape corresponding to the equation

$$\tau = C \sin^2\omega \sin(2nt+2\lambda)$$

produce pressure-waves having the form corresponding to the equation

$$\varepsilon = -C \sin(2nt+2\lambda)[37.99 \sin^4\omega + 23.06 \sin^6\omega + 5.75 \sin^8\omega + \ldots]$$

The factor $\sin^4\omega$ jumps from $-\infty$ over to $+\infty$ when the temperature is near $T_0 = 268°$. On the other hand, if the temperature of the atmospheric spherical shell is nearly 268°A., then slight semidiurnal temperature-waves are able to produce large pressure-waves in air that is devoid of friction. We should thus have a physical explanation of the diurnal change of atmospheric pressure that we can restate as follows: The physical cause of the diurnal change of atmospheric pressure is to be found in the diurnal change in temperature; the principal pressure-wave is the semidiurnal, and is produced by the semidiurnal wave of temperature. Although this last is small, yet it produces a considerable semidiurnal wave of pressure because for an average temperature of about 268°A. the atmosphere has very nearly the period of the forced vibration that closely approximates its free vibration and this is not true of the 24-hour oscillation of temperature. On the basis of this knowledge it would then become possible to construct the correct mathematical expression for the diurnal curve of pressure.

But many doubts attach to this explanation. Margules himself says:

> Its application to the diurnal barometric variation is clear in one respect only; the semidiurnal wave of pressure can also be considered as the consequence of a semidiurnal temperature-wave of small amplitude. This theory explains the relative magnitude, but not the uniformity of the semidiurnal wave of pressure above the land and the ocean. * * * The neglect of the friction and of the vertical motion of the air in our last computation, *the assumption of a uniform average temperature in the whole mass of air* and the assumption of the equality of the oscillation throughout any given latitude, allows us to make only a vague application of this prinicple.

And thus we come back to the original point of view that Margules expresses in his introduction: "If we consider this semidiurnal wave of pressure as a consequence of the changes of temperature, still the connection is very obscure."

I can not resist expressing the most obscure feature of this matter, viz, that the very existence of a semidiurnal wave of temperature is not proven or even made probable. I need not repeat what I have said at the conclusion of the chapter on the variation of temperature and the interpretation of Bessel's sine series. I need only emphasize the fact that we have no right to attribute to the one-half daily wave of temperature a reality that does not belong to it, since it is only a mathematical auxiliary, in order to arrive by pure mathematics at the construction of a curve that nature arrives at in another way well known to us by means of the temperature. And yet only an actual double daily wave of temperature having two actual maxima and minima can be the physical cause of the actually existing double daily wave of pressure.

Must we, therefore, give up the temperature wave as a cause of the double diurnal pressure wave and again return to an at least equally obscure "cosmical cause" as its origin?

On this point I allow myself to sketch some thoughts which appear to me to be worth a closer examination, and that I hope to be able to give thorough and accurate attention in some other place. If we consider the earth with its atmosphere as a unit, then there is always one whole hemisphere warmed by solar radiation, and the quantity of heat that the earth receives from the sun is always the same—excepting for changes of the sun itself and the periodic annual changes of the distance of the sun from the earth. The illumined hemisphere considered as a whole will, therefore, always receive a nearly constant amount of heat. This is the basis of the remarkable constancy of the amplitude of the semidiurnal wave of pressure which has repeatedly led to the assumption of a "cosmical cause." We thus have this constant cosmic cause before us. How does the semidiurnal wave of pressure arise, since the sun comes to each meridian only once every day? I think of this as analogous to the tides of the ocean. The moon also passes through the meridian but once a day; but we know that the tide arises simultaneously in the meridian and 180° therefrom and we know why, and that thus the semidiurnal tide is brought about. As to the double wave of atmospheric pressure, something similar occurs: On the hemisphere that is heated directly the surfaces of equal pressure in the atmosphere are elevated—most strongly in the region where the warming is the greatest—therefore air flows toward either side toward the hemisphere that does not receive radiation from the sun. Hereby a mass of air is drawn from the illumined hemisphere and carried over to that which is not illumined. Now, the consequence of this shifting of masses on the earth would directly produce a shift in the position of the center of gravity of the whole system, earth–air. According to a well-known law in mechanics the center of gravity of a free floating body is invariable, a change of position of certain free masses on the body produces a compensating change of position of other free masses. Under our conditions then, according to this theorem, masses must flow away from the region 180° distant and the accumulation of masses must also be so arranged that they will attain their maximum at 180° from each other and at 90° from the places whence the masses flow. Thus the change of the center of gravity is prevented. Thus we should have two maxima and two minima of pressure that must continually circulate around the globe with "cosmic" regularity.

Most of the causes that have been adduced by different meteorologists in explanation of the diurnal change of air pressure, very probably do bring about various modifications. Thus I hold it to be fairly certain that the morning maximum becomes the principal maximum by reason of the tension [see above p. 658] conceived of by Espy and by several others down to Angot. Again the horizontal motions of the air make their influence felt and possibly also the dynamic pressure of the sinking atmosphere during the evening maximum comes into consideration. In short, the individual processes above mentioned may all be plausibly considered as modifying causes. But I will not here enter into these details. The idea of a mechanical explanation for the "cosmic" regular semidiurnal wave of pressure briefly sketched above can easily be further extended by anyone. It seems unnecessary to multiply words on the subject. If I am able to compute the relative magnitudes that result from this cause, then I will on some other occasion endeavor to give a detailed theory of the diurnal changes of pressure based upon the above-mentioned foundation.

This report on the present condition of the theory of the daily periodic pressure changes must unfortunately be rather elaborate because no well-established theory exists, but from what has been stated one can really attain a complete picture of the condition in question.

I will summarize my report as follows:

The diurnal temperature variation is the fundamental cause of the diurnal oscillation of the barometer. The "cosmic" regularity of the semidiurnal wave of pressure has its origin in the solar heat which is constant to the whole earth; and has its mechanical cause in the theorem of the constancy of the center of gravity of free, floating bodies. A number of consequences from the diurnal march of temperature, such as the horizontal and vertical air currents, evaporation, the tension of air warmed at the surface of the ground, etc., may modify the original wave of pressure. A physically intelligible theoretical mathematical expression based upon the physical causes of the diurnal curve of pressure is still lacking. A sine series of Bessel that is used instead of this deductive formula reproduces the phenomenon very exactly when we develop it to the 3-fold angle and gives us especially a good insight into the character of the semidiurnal wave of pressure that we have recognized as the principal wave of pressure.

III. EXPLANATION OF THE DIURNAL CHANGE OF THE WIND.

In reference to the wind, we have to consider two elements for the investigation of its diurnal changes—the direction of the wind and the velocity of the wind.

It is necessary to remark at the outset that the condition of our knowledge of the facts relative to this diurnal change is considerably worse than for temperature or pressure of the air, and corresponding thereto we have a smaller number of attempts to explain the phenomena. In order not to be too verbose, we must here also restrict ourselves to the explanation of the phenomenon and assume its details to be well known.

One peculiarity occurs in the case of the winds that we must take cognizance of first. The wind is a motion of the air, and in such motions the resistances to motion play an important part. In our case the friction of the wind against the earth and the obstacles presented by its various topographic forms is the cause of many peculiarities. We here have to do with a stratum of air adhering more or less to the surface of the earth, which evidently must have its own peculiar conditions. At an altitude above the earth that is not especially high—at any rate less than 300 meters, as shown by the observations on the Eiffel tower—the free movement of the air is demonstrably present.

Since we are primarily concerned with a general problem of the atmosphere, we will first consider the unrestricted moving air, that is to say, the diurnal period of the direction and velocity of the wind of the higher free strata of air. We will then consider the diurnal period of the air in the lowest strata near the earth in all its peculiarities and be in a position to understand them as a result of the phenomena in the upper strata and the friction of the lower strata at the earth's surface.

This may seem like a new method of treating the subject, and it may be that I shall depart somewhat thereby from my problem to depict the present state of the question; but we shall find an accurate presentation of the matter, although I must also say, by way of introduction, that we have little knowledge of the subject.

A. DIURNAL CURVE OF THE WIND IN THE UPPER AIR STRATA.

1. *Direction of the wind.*—I have, as I think, demonstrated (28) that undoubtedly "the wind changes with the sun." The explanation of this phenomena I find in the fact that where the sun stands in the meridian the column of air is raised to the greatest extent, and therefore in the strata above the isobaric surfaces must also be raised so that through the whole column there is a barometric gradient from this region of greatest warming toward the regions of lesser and least warming. In the morning hours the sun stands in the east, which is therefore the region of greatest warming. Thus there arises a gradient from the east and in each case, if other causes have not caused a stronger gradient in some other direction, easterly winds will arise. In the evening this region of strongest warming lies to the west of us, and under the same conditions we have westerly winds. For the temperate latitudes and about midday, however, a south-to-north gradient must develop because the greatest warming then takes place in the south, and thus under these conditions south winds must prevail. Therefore, day after day the wind goes round with the sun, as the observations also demonstrate.

2. *Wind velocity.*—The diurnal march of wind velocity is ordinarily computed without regard to the direction of the wind. In such cases it is certain that the minimum must fall somewhere near the midday hour and the maximum velocity near midnight.

But the question remains whether this holds good for every wind no matter what its direction. I have investigated this question (29) without coming to any certain conclusion. It is quite possible that the diurnal march, without regard to the direction of the wind, may be only the resultant of the diurnal march of the totality of the individual wind directions. In fact, I found for the summit stations Sonnblick, Säntis, Obir, Pikes Peak, Pic du Midi, and Puy de Dôme, a rather variable time of occurrence of the maximum in particular, and the minimum also, for the different wind directions. According to the above given explanation of the daily march of wind direction, a different diurnal march is to be expected for each different direction of the wind, such that the east wind should have its maximum in the morning hours, the south wind at the time of maximum temperature, and the west wind in the evening. For it is clear that any gradient that produces an east wind will be increased most decidedly in the morning, whereas during these hours a gradient that produces a west wind will be most enfeebled. Similarly, a south wind considered as a consequence of the general distribution of pressure, will be strongest at midday; a similar west wind will be strongest in the evening, each being a consequence of the increase of the corresponding gradients for these hours. But this explanation does not completely correspond to any one of all the mountain stations investigated by me. The Sonnblick station is the only one that shows the anticipated time of beginning of the east, south, and west winds, but even then only for the simple wave of the diurnal march represented by the Besselian series. On the other hand, the amplitude of the 2-fold wave shows such a large value—it is indeed much larger for the east wind than the value for the simple wave—that this result also appears to be less satisfactory. At first glance the diurnal march for the different directions of the wind shows that except for the south wind on the Sonnblick, particularly the minimum always occurs near midday. Therefore, after the investigation of the diurnal march of wind velocity for the individual wind directions in general, there remains a curve such as shows the minimum about midday, whereas the maximum occurs sometimes during evening, sometimes at night, sometimes during the morning hours.

Hence I conclude that two causes determine the diurnal march of the wind velocity: (1) For the east, south, and west winds, the above-given increase of the gradient during the morning, midday, and evening, respectively. To this cause also I ascribe the different hours of the occurrence of the maxima. (2) A disturbing cause occurring uniformly about midday for all winds. This latter disturbing cause I believe to be the friction which occurs in the upper strata by reason of the warmed ascending air. As is well known, it has been shown by several, and especially by von Helmholtz (**30**), that the internal friction of the air is an entirely negligible quantity when we consider smooth surfaces of separation (glatte Trennungsfläche), but that this becomes appreciable when two layers flowing at different velocities send streamlets (Strömchen) into each other. The latter process occurs particularly during the noonday hours in the upper strata of air, and in consequence thereof the velocity of the upper air decreases at that time.

I do not deny that this explanation may in general agree with that given by Koeppen (**31**) and Sprung (**32**), although these two investigators also attributed the delay to the *slower-moving* lower air masses that are ascending. But after all in this case also "friction" will also come out as a hindrance.

Another question is, how high in the free atmosphere this influence will make itself felt. On the Eiffel tower it is decidedly present, and this is easily explained by the intrusion of air ascending from the nearby surface of the earth. On the mountains the lower air ascends to the top as a valley wind, but whether at altitudes comparable with the Säntis and Sonnblick interchange of air in the free atmosphere with the lower strata still exists, seems to me very doubtful. As I believe, the diurnal march of wind velocity for the individual wind directions at those altitudes must be simply and only determined by the march of the sun itself, as was the case with the wind direction. Therefore I hold fast to the conclusion that this is also the principal cause of the diurnal march of the wind on mountain summits, and that the midday friction explained above is only a modifying cause.

B. DIURNAL CURVE OF WIND IN THE LOWER STRATA OF AIR.

In this case I do not separate the treatment of the wind direction from the wind velocity because they both seem to me to allow of a single explanation.

As far as concerns the wind direction, it is in general true at all stations for which hourly observations are at hand, and where the land- and sea-breeze of the coast or the mountain and valley winds in the interior do not exercise a local control, the following theorem holds good: "The wind changes with the sun the same way as in the upper strata." This must seem quite remarkable. Not less peculiar does it appear that the diurnal march of wind velocity for all directions rises throughout the day to a maximum, but during the night time sinks to a minimum (**33**).

Now it seems to me that the explanation of these two phenomena is to be sought in the fact that in both cases the lowest strata of air regulate their behavior by the influence of the upper strata. If we first disregard all temperature influences then, during the nighttime, the lower strata of air are held by friction with the surface of the earth and thus possess a much smaller velocity than the air masses flowing smoothly above them. During the day the lower strata are warmed, they both expand and also send their streamlets (Strömchen) into the upper strata; and in consequence of the resulting friction between the upper and lower strata they are dragged along by the upper layer and set into a more rapid motion. Hence in the upper strata there is produced a diminution, but in the lower strata an increase in velocity; and thus is explained the maximum of wind velocity in the lower strata at the time when the upper strata have their minimum. This also explains the nocturnal minimum of the lower strata, because then the friction is absent and they are left to themselves.

Precisely as with the velocity of the wind, so also the wind direction is determined during the day by the upper strata and for the same reason. Thus we may explain the fact that the wind direction in the lower strata also "changes with the sun." Here also we must recognize the fact that Köppen and Sprung (**34**) have also referred this phenomenon to the influence of the upper strata, but they suppose the more rapidly moving air sinking from the upper stratum to be its cause. There are, however, two points to be considered here: First, the march of wind direction does not agree with that demanded by their theory (**35**); and second, as to the wind velocity, the following modification has been made: since the observations on the Eiffel tower have been available it is scarcely to be assumed that the "lower" strata—the ones we are here concerned with—extend up as much as 100 meters above the ground. This lowest stratum will, to be sure, not only send air upward during the warming of the morning hours, there must also be air descending from above; but as the warming progresses the sinking air will not reach the lowest stratum since, in consequence of its expansion, the warmer air below while transferring a portion to the upper stratum will require a decreasing quantity to replace the loss because it itself requires more space below as it expands under the general spread of the warming up. Much more might be said with regard to this process, but all leads to the same result, that we can no longer appeal to descending air entering the lowest strata precisely at the time of the lower maximum in that stratum. This is the reason why I adhere to the explanation I gave above for this phenomenon of the diurnal march of the wind in the lower stratum of air.

SUMMARY.

It would seem unnecessary to attempt any more profound words relative to the main point of my problem, viz, to bring out the mechanico-physical connection between the phenomena of the daily periodic march of temperature, pressure, and wind in the atmosphere. Everything that has hitherto been said shows its dependence on the march of temperature which itself again depends on the radiation from the sun. And thus we of course again are driven to the central cause of all physical processes in our planetary system.

NOTES AND REFERENCES.

I. *Temperature.*

(1) **Lambert.** Pyrometrie, pp. 322 and 141.
(2) **Weilenmann** in Schweizerische Meteorologische Beobachtungen. 1872, **9** Jhrg.; p. XLVII.
(3) **Maurer** in Schweizerische Meteorologische Beobachtungen. 1885, **20** Jhrg.
(4) **Trabert.** Der tägliche Gang der Temperatur und des Sonnenscheins auf dem Sonnblickgipfel. Denkschriften der math.-naturw. Classe der K. Akad. d. Wiss., Wien [dated 15. October 1891], **59**. Band, p. 177, ffg; p. 205.

Maurer assumed that the coefficient of radiation of the atmosphere, σ, referred to the unit of volume and was therefore independent of the density, ρ. Consequently he expressed the differential equation by

$$\rho c \partial T = \sigma(T - T_0)\partial z,$$

the integral of which is

$$T = T_0 + Cb^z, \text{ where } b = e^{-\frac{\sigma}{\rho c}}$$

From the observations on the Sonnblick, Trabert computed the value of b and found it as large as for the stations on the lowland. If b were independent of ρ, then it must have been much smaller. Other high stations also show that b is independent of ρ. Hence Trabert concluded very properly that the coefficient of radiation referred not to the unit volume, but to the unit of mass, and was therefore independent of ρ. Therefore the differential equation should read

$$e \partial T = (T - T_0)\sigma \partial z,$$

and the integral should be

$$T = T_0 + Cb^z$$

where b has the value $e^{-\frac{\sigma}{c}}$ which is, of course, slightly different from its value in the previous equations.

But it is now remarkable that b varies with the time of year, and therefore we arrive at the hypothesis that it varies with the temperature. This dependence upon temperature must, however, be recognizable by the comparison of tropical stations with those in higher latitudes. Trabert investigated 42 stations by groups, distributed over all latitudes, and did not find any dependence of b on the temperature. He explained the annual change of b by the method of computing b. *See* **Trabert,** "Die Wärmestrahlung der Atmosphäre." Met. Ztschr. 1892, **27**:41.

(5) **Lambert.** Pyrometrie, p. 322.

(6) **Lambert.** Pyrometrie.

The final form which Lambert gives to the formula for the daylight portion of the diurnal curve is as follows:

$$\frac{2y}{\cos p \cos \delta} = 2\sin\varphi + \sin\omega + \cos\omega + \sqrt{2}\sin(45 - \varphi)\, e^{-(\frac{1}{2}\pi + \varphi + \omega)}$$

where ω is the hour angle counted from noon (local mean time), e is the altitude of the equator, p is the altitude of the pole or the latitude of the place, δ is the declination of the sun, and φ the true anomaly of the sun. According to this formula he computed a table of the values of $\frac{2y}{\cos p \cos \delta}$ for the successive lengths of the day between 6 and 18 hours. In order to obtain the ordinate y, the values of that table must be multiplied by $\frac{1}{2}\cos p \cos \delta$. This value of y is therefore nothing else than the elevation of the ordinate above that abscissa which passes through the minimum value. The accuracy of the value thus obtained leaves much to be desired.

(7) **Lamont.** Darstellung der Temperaturverhältnisse auf der Erdoberfläche, p. 10.

The Lamont formula reads:

$$t = l + pz + q\cos(z + \varepsilon);$$

this is a purely empirical formula, since he made no attempt to express physically the important terms in the radiation.

(8) **Weilenmann** as above quoted, puts the rate of warming equal to ap^ε and the rate of cooling equal to kp^ε, and thus made all quantities proportional to the radiation. Thus the warming of the ground was

$$bp^\varepsilon \cos\xi;$$

where ξ is the zenith distance; the cooling of the ground by convection was

$$\lambda p^\varepsilon \cos\xi;$$

the cooling of the ground by heat radiated to the air was

$$h(t' - t);$$

and the cooling of the ground by radiation of heat to the upper strata of air was

$$h(t' - u);$$

in all which formulas t = the temperature of the air, t' = the temperature of the ground, u = the temperature of the upper air strata, and z = the time. His differential equations read

$$\frac{\partial t}{\partial z} = (a - k)p^\varepsilon + h(t' - t)$$

$$\frac{\partial t'}{\partial z} = (b - \lambda)p^\varepsilon \cos\xi - h(t' - t) - h(t' - u).$$

By the combination of these two equations Weilenmann found

$$\frac{\partial^2 t}{\partial z^2} + 3h\frac{\partial t}{\partial z} + h^2 t = h^2 u + p^\varepsilon(a\pi\frac{\partial \varepsilon}{\partial z} + 2h\alpha + h\beta\cos\xi)$$

$$\alpha = a - k; \text{ and } \beta = b - \lambda.$$

The integral of this equation is not to be taken smoothly. By various manipulations Weilenmann brings it into the following form

$$t = u + [c_1 + c_2(z + b^{Z+z})]b^Z + (\xi_1 + \xi_2 \sin Z + \xi_3 \cos Z)p^\varepsilon;$$

where Z is the semidiurnal arc, and the constants u, c_1, c_2, b, are to be determined by the nocturnal observations, and the constants ξ_1, ξ_2, ξ_3, and p are to be determined by the daylight observations. One can not say that the equations are easily handled and their deduction dose not imply their correctness.

(9) **Angot.** Sur la variation de la temperature à Paris. Annales, Bureau central météorologique de France. Year 1888, I.—Memoires, page B135.

Angot is certainly the only one who has systematically separated the daylight and nocturnal branches in the computation.

(10) **Wild.** Die Temperaturverhältnisse des russischen Reiches. p. 4–6.

II. *Atmospheric pressure.*

(11) We certainly owe this knowledge first of all to the industrious observers who have been and still are active for a long series of years over the whole earth. We are also greatly indebted to many meteorologists who have worked over and published these observations. But our chief gratitude goes out to those who have collected the scattered observations and have discussed them from a single point of view; among these we must mention above all others Rykatchev, Hann, and Angot.

Rykatchev. La marche diurne du baromètre en Russie. Repertorium für Meteorologie, t. **6**, No. 10.

Hann. Untersuchungen über die tägliche Oscillation des Barometers. Denkschriften der K. Ak. d. Wiss., Wien, 1889, math.-naturw. Cl., Bd. **55**, p. 49.

Weitere Untersuchungen über die tägliche Oscillation des Barometers. 1892, Bd. **59**, p. 297.

Angot. Étude sur la marche diurne du baromètre. Annales, Bur. central mét. de France, Year 1887, I—Mémoires, p. B237.

For the high stations we must also add:

Pernter. Ueber den täglichen und jährlichen Gang des Luftdruckes auf Berggipfeln und in Gebirgsthälern. Sitzungsb., K. Ak. d. Wiss., math.-naturw. Classe, II. Abth., Wien, 1881, **84**.

(12) **Dove,** in Poggendorffs Annalen, 1831, **22:** 219; 1842, **58:** 177; and Sitzb., preuss. Akad., Berlin, 1860, p. 644.

(13) **Ramond.** Mémoires sur la formule barométrique de la mécanique céleste et les dispositions de l'atmosphère qui en modifient les propriétés. Clermont-Ferrand, 1811, pp. 89–92. (Troisième mémoire lu à la Classe des sciences physiques et mathématiques de l'Institut les 5, 12 et 26 décembre, 1808. Imprimé dans les mémoires de la Classe, année 1808, 2e semestre, p. 73.)

The paragraph in question, translated from the French, reads as follows:

> Considered from this point of view, the phenomenon seems to me to be susceptible of a very satisfactory explanation. While the sun is in our meridian it warms that part of the globe comprised between the places of its apparent rising and setting. Let us suppose that this warming becomes sensible from the 9 a. m. circle to the 3 p. m. circle. The air expands; the surface of this portion of the atmosphere rises above the level of the neighboring layers and discharges some of its excess upon them. The barometer falls, but at the same time it necessarily rises in the regions comprised between the circles of 3 p. m. and 9 p. m., and between the circles of 3 a. m. and 9 a. m., for within these two regions the air is condensed by the cold of the morning and of the evening; the surface of the atmosphere is depressed and this depression is filled little by little by the overflow from the higher layers of the two neighboring regions. Thus the movement is propagated step by step and communicates itself to that part of the atmosphere that is embraced between the two nocturnal circles. The barometer falls, therefore, from 9 p. m. to 3 a. m. because the air has lost its density by the diminution of the cold which took place in the middle of the night and has lost its height by reason of the tribute that the higher layers have paid to the two limiting regions.

(14) **Espy** *in* Report of the British Association, 1840 (Glasgow), Notices and abstracts, page 55.

He says:

"When the sun rises the air begins to expand by heat; this expansion of the air, especially of that near the surface of the earth, lifts the strata of air above, which will produce a reaction causing the barometer to rise; and the greatest rise of the barometer will take place when the increase of the heat in the lower parts of the atmosphere is the most rapid, probably about 9 or 10 a. m."

With reference to the nocturnal maximum, Espy says:

"As the barometer now stands above the mean (at 9 or 10 p. m.), it must necessarily descend to the mean at the moment when it is neither increasing nor decreasing in temperature, which will be a little before sunrise."

(15) **Kreil. Ueber die täglichen Schwankungen des Luftdruckes. Sitzb. d. K. Ak. d. Wiss., Wien, 43: 121.**

Kreil states that he will try "to explain the diurnal variation of barometer by the changes of temperature without utilizing any other cosmical force."

"Of course we must consider not merely the different temperatures, but also all other direct and indirect consequences of the increasing and diminishing temperatures, such as the greater or less *tension* of the inclosed and compressed air masses; the *elasticity* of air in consequence of which when pressed on one side it does not immediately set up a progressive motion, but is at first compressed on the side of the pressure; its *inertia*, according to which when once air is set in motion it continues in motion even when the cause of the motion no longer exists; the heat which the ground absorbs and radiates outward; and above all the ascending and descending motion of the air masses."

On page 131 he summarizes all this as follows:

At sunrise the lowest stratum of air, by reason of the cooling of the earth's surface, finds itself in a condensed and by the sinking of the upper strata of air, also in a compressed condition. The tension of this lowest air is further increased by the gradual warming of the ground and the air, hence the pressure on the barometer increases still further and in fact until the ascending air current produced by the sunshine attains such strength that the diminution of pressure produced by it overcomes the increase of tension produced by the increasing temperature. This is the instant of the maximum, and from this point onward the atmospheric pressure diminishes and more rapidly in proportion as the ascending current is stronger.

This is Kreil's explanation of the morning maximum and the afternoon minimum. The evening maximum is attributed to the descending current of air. His explanation of the nocturnal minimum is quite peculiar, and is as follows:

But the atmosphere in this condition is again not in equilibrium; for, by reason of the cessation of the motion from above downward, the lowest, compressed air strata acquire an excess of force that must manifest itself by pressing upward against the air that rests upon it. Thus arises again an upward motion that, although very much slighter than that of the previous morning, must bring about a diminution of atmospheric pressure and lead to the minimum that occurs after midnight.

(16) **Lamont** *in* Sitzungsb. der bayerischen Akad. d. Wiss., 1862, 1: 95, ffg.

(17) **Blanford** *in* Proc., Asiatic Society of Bengal, 1876, No. VIII, p. 176; Proc., Royal Society, London, **44**: 411. In this latter memoir he says:

But in 1876 * * * occurred to me that Lamont's assumption, that the atmosphere is free to expand vertically, lifting the superincumbent mass, is subject to an important modification which may greatly alter the conditions of the problem as contemplated by him.

These conditions take no account of the resistance to expansion that must be opposed by the highly attenuated but extremely cold external atmospheric strata of great but unknown thickness, the existence of which is proved by the phenomena of luminous meteors.

(18) **Angot.** Étude sur la marche diurne du baromètre, [see (11)], p. 342:

Starting with sunrise, the lower layers of air warm up rapidly and tend to rise; but this movement will only be produced later when the warming shall have been sufficient to be communicated to the upper regions of the atmosphere; in the first hours after sunrise the lower layers remain in place, warm up and expand, whence an increase in their elastic force and the more rapid rise of the barometer.

(19) **Rykatchev.** La marche diurne du baromètre en Russie [see (11)].

He analyzes the winds into their N–S and E–W components and eventually attains the following results:

During the daytime, viz, from 8 or 9 a. m. up to 5 or 7 p. m., the air moves from west to east; during the nighttime the motion is from east to west; the air moves with greater velocity by day than by night.

To-day we know how erroneous all this is, and we have explained this in chapter III on the diurnal curve of the wind. Rykatchev founds his theory on this assumption. He says:

Thus above each unit of surface of the ground the mass of air will increase up to the mean result by $\frac{24k}{2\pi} dv$; consequently the total pressure of the atmosphere on the unit surface will augment to an extent proportional to dv; hence the variations in pressure produced by the lower air currents are proportional to the variations of the velocity component in the east-west currents.

Having come to a similar conclusion with regard to the upper currents, he arrives at the following more complicated theory:

The morning maximum.—From 6 a. m. up to 2 p. m., the lower current contributes to the rarefaction of the air and to the diminution of pressure; during this same time in the upper layer the warm current from the east becomes stronger and stronger; the warmed-up air accumulates more and more above the lower, comparatively cold air; at the commencement the increase of pressure, produced by the current of the upper air, is greater than the diminution caused by the current of the lower air, and the sum total of these pressures increases up to 10 a. m., when the barometer attains its maximum. From this moment the pressure of the upper layer steadily continues to increase, but slowly; the influence of the lower layer becomes predominant and the barometer commences to fall.

The afternoon minimum.—On the approach of the hour of maximum temperature, the warm current from the east in the upper layer begins to diminish to such a degree that a greater quantity of air flows along this layer toward the west than toward the east. The pressure depending on the current of the upper layer diminishes; the current from the west in the lower layer contributes to the fall of the barometer up to 2 p. m.; then it acts in a contrary direction, but after attaining its maximum velocity the current varies but little in velocity and its influence is feeble, the barometer continues to fall until 4 p. m. After this the influx of air by the lower current reacts upon the diminution of the air produced by the upper current.

The afternoon maximum.—The current from the west in the lower air becomes more and more feeble; soon it is replaced by the current from the east and then the velocity increases until nightfall; consequently during all this time the current of the lower stratum increases the pressure. In the upper layer at the moment of maximum temperature the air's inertia keeps it moving from the east, this current diminishes in velocity and its direction changes. This movement of the air from the east, commencing feebly, increases in velocity; thus the pressure of the upper layer diminishes; but until 10 p. m. the influence of the current of the lower layer is predominant and the barometer rises; after this time it is the current of the upper layer which exerts the greater influence on the trend of the barometer; the total pressure of the atmosphere commences to diminish.

The nocturnal minimum.—Passing afternoon maximum, the pressure of the upper layer continues to diminish until 4 a. m.; the current of the lower layer during the night exerts almost no influence on the trend of the barometer; during all the time from midnight to 6 a. m. its velocity is almost constant; the barometer falls until 4 a. m.; afterward in the upper layer the current from the east is delayed by the opposing current which replaces it and becomes stronger and stronger; then the barometer ought to rise.

(20) **Liais.** Théorie mathematique des oscillations du baromètre. Paris, Bachelier. 1851.

Whoever, misled by the title of the pamphlet, expects a mathematical treatment of the causes that are enumerated will be disappointed.

(21) **Peltier.** Recherches sur la cause des variations barométriques Académie Royale de Bruxelles. Extrait du tome XVIII des mémoires cour. et mim. des savants étrangers.

Peltier described the fundamental principle of his explanation on page 66, saying: "One of the more immediate effects of these electric attractions and repulsions is to form an atmosphere either heavier or lighter, and consequently they are the cause of the numerous variations that the atmospheric pressure experiences."

(22) **Hann.** Untersuchungen über die tägliche Oscillation des Barometers. See (11) page 52, where he says:

"(This investigation) will have for its main object nothing more than a strict scientific description of the atmospheric tides, and thus form the foundation for a subsequent mathematico-physical theory of them."

(23) **Lamont,** *in* Sitzungsb. d. bayerischen Akad. d. Wiss., 1862, Bd. 1, page 113, writes:

Whereas in the previous table, representing the first term of Bessel's sine series, there resulted an excessive influence of the locality; we find here, in the term for the 2-fold hour-angle, a remarkable agreement as to epochs, and a regular diminution in the magnitude of the motion from the Equator to the poles, whence there can be no doubt that here we have to do with a general phenomenon conditioned only in a very slight degree upon the locality.

And on page 118:

These tables give, as I believe, the complete demonstration as to the correctness of my proposed explanation for the diurnal motion of the barometer, inasmuch as on the one hand they show that the first term increases and diminishes in exact harmony with the monthly curve of the temperature of the air and therefore appears as the effect of the temperature, while the second term—whether we consider northern or southern, higher or lower stations—always has the same form and both because of its double period in 24 hours as well as on account of its independence of the season of the year, can not be ascribed to any direct or indirect influence of temperature.

And again on page 122:

I consider these facts, together with the facts above mentioned, as a distinct demonstration that the ebb and flow of the atmosphere must be ascribed to some cosmical force.

These last thoughts he develops still further in the Bulletin de Bruxelles, classe des sciences de l'Académie royale 1859, t. **26**. On page 137 he says:

Now what is the force that produces this regular motion of the atmosphere? As it is evident from the first that the effect is due to a direct or an indirect action of the sun, the first force to which we would naturally attribute it is gravitation which produces a similar movement in the layer of water that covers the earth. * * * But as the movement due to lunar attraction is only $\frac{1}{15}$ of a Paris line near the Equator, it is impossible that the much weaker action of the sun could produce a movement of more than $\frac{1}{4}$ a Paris line. * * * One is finally led to the conclusion that the heat of the sun together with all that depends upon it, can not explain the oscillations of the barometer and that it is necessary to attribute these to a force similar to that of gravitation which, like it, produces in a fluid layer covering the surface of the globe the same effect on points diametrically opposite. Among those forces, whose existence has been recognized or assumed, there is only a single one that meets this condition; and this is the force of electricity which is undoubtedly manifested in cometary phenomena. In fact, let us assume that the sun possesses a great quantity of positive electricity, and that this electricity acts upon an isolated fluid sphere. The two electricities will be separated within the sphere by induction and the hemisphere that is turned toward the sun will be attracted while the opposite hemisphere will be repelled, so that the whole fluid sphere will assume an oval form. Thus the action of the sun's electricity will produce in our atmosphere an effect similar to that which gravitation produces in the waters of the ocean, and the same force that produces the diurnal motion of the magnetic needle will serve to explain the diurnal oscillations of the barometer.

(24) See the memoirs quoted under (2).

Hann has devoted a great number of additional studies, either wholly or in part, to the investigation of the periodic diurnal variations of pressure. This is not the place to enumerate all these; but I would refer to the brief memoir:

Hann. Bemerkungen zur täglichen Oscillation des Barometers. Sitzungsb. K. Ak. d. Wiss., math.-naturw. Cl., Wien, 1886, **93 II: 981.**

In this memoir Hann throws out a new thought toward the explanation of the constant semidiurnal wave of atmospheric pressure. He asks whether possibly the absorption of the radiant heat from the sun by the upper strata of the air can be the source of this wave and of its constancy.

It is easy to perceive that by the periodic diurnal influence of the solar rays on the upper layers of the atmosphere occurring similarly day after day, periodic motions of great regularity must arise in the upper strata of the atmosphere, viz, an oscillation of the whole mass of the atmosphere. These motions can explain the typical character of the diurnal oscillations of the barometer, whereas the local differences represent the basis of the element that modifies the result.

We here see that Hann had correctly appreciated the *amplitude* of the double wave of pressure.

In this elegant little memoir it is interesting to perceive the demonstration that the magnitude of the amplitude of this wave has nothing to do with sun-spots, whence Hann correctly draws the following conclusion:

This diurnal oscillation of the pressure can not depend on the electricity of the sun, as was thought by Lamont, for in that case it must certainly have a period in common with the magnetic variations which evidently depend upon the sun-spot period.

(25) **Angot.** Étude sur la marche diurne du baromètre. [See (11).] On page B311 he says:

An examination of the figures in Table 4 shows that the semidiurnal wave is a complex wave resulting from the interference of two distinct waves. One of these, which we shall call the *secondary semidiurnal wave*, presents one maximum and one minimum in the course of the year like the diurnal wave and, like it also, is influenced by local conditions. * * * This secondary wave is then certainly due, like the diurnal wave, to the diurnal variation of the temperature of the lower layers of the atmosphere. The second wave, which we shall call *the principal semidiurnal wave*, presents very different characteristics; its amplitude experiences a double variation in the course of the year; it is a maximum at the two equinoxes, and a minimum at the solstices. * * * One can indeed already foresee that the phase of this second wave for one and the same station is constant throughout the year.

Again on page 338 Angot says:

The diurnal curve of the barometer can be considered as the resultant of the superposition of two waves having very different origins and characters. One of these waves is independent of the special geographic conditions of each station; it depends only on the position of the sun in its orbit and on the latitude.

After Angot has remarked that perhaps it may be possible that this "semidiurnal, principal wave" also has a term containing the 4-fold angle ($\phi+4x$), but in that case its amplitude certainly can not be even 0.02 to 0.03 mm., he then proceeds to say:

The second wave can be represented by a series such as

$$a_1\cos(x+\phi_1)+a_2\cos(2x+\phi_2)+a_3\cos(3x+\phi_3)\ \ldots$$

This wave is caused, at least in great part, by the diurnal variation of temperature in the lower layers of air, and consequently all its coefficients depend not only on the latitude and the season but equally on the particular situation of each station; the coefficients change their values with every change of condition and every local influence that can modify the diurnal variations of temperature; we are therefore justified in calling this second wave by the name "thermal wave."

(26) **Margules.** Ueber die Schwingungen periodisch erwärmter Luft. Sitzungsb., K. Akad. d. Wiss., math.-naturw. Kl., Wien, 1890, **99**: 204–227.

Translated in—

Abbe, C. Mechanics of the earth's atmosphere. Washington, 1891. (Smithsonian misc. coll. No. 843.) pp. 296–318.

(27) **Thomson, Sir W.** On the thermodynamic acceleration of the earth's rotation. Proc. Royal soc., Edinburgh, 1882, **11**: 400. *See* Margules (26), page 207.

III. *Wind.*

(28) **Pernter.** Die Windverhältnisse auf dem Sonnblick und einigen anderen Gipfelstationen. Denkschr., Kais. Akad. d. Wiss., Wien, **58**: 209, ffg.

(29) **Pernter.** Idem, pages 206 and 207.

(30) **Helmholtz.** Ueber atmosphärische Bewegungen. Sitzungsb., Kgl. preuss. Akad. d. Wiss., Berlin, 1888. *Reproduced in* Meteorologische Zeitschrift, 1888, **23**: 329.

Translated in—

Abbe. Mechanics of the earth's atmosphere. Washington, 1891. (Smithsonian misc. coll., No. 843.) pp. 78–93.

(31) **Köppen,** in his remarks on Hann's great work:
"Die tägliche Periode der Geschwindigkeit und Richtung des Windes." Sitzungsb., d. Kais. Ak. d. Wiss., 2 Abth. Wien, **89**: 11 ffg.; *also in* Meteorologischen Zeitschrift, **14**: 343; and more extensively in Annalen d. Hydrographie, **11**: 625.

(32) **Sprung.** Lehrbuch der Meteorologie, page 341.

(33) Almost every trace of variation in the diurnal curve is lacking on the ocean.

(34) **Sprung.** Deutsche Meteorologische Zeitschrift, **1**: 15.

(35) The many additional items added by Sprung by counting the rotation of the windvane, are based in general on observations made only three times a day, and this insufficient observational material may certainly explain the result attained by him.

ON THUNDER.[1]

By WILHELM SCHMIDT.

[Dated K.k. Zentralanstalt für Meteorologie u. Geodynamik, Vienna, 1914.]

1. From earliest times a thunderstorm, and particularly the thunder and lightning, has made the greatest impression on man. It is, therefore, all the more strange, that precisely these phenomena have remained so little studied, and that our knowledge of the sound phenomena has not been increased by more experiments that are something more than analogies. And yet it is not at all difficult to secure results in this field. Observations that may be made when it thunders, themselves point the way to such experiments. Beside the extremely violent, usually deep-toned peals—though they sometimes have a clear ringing or a rushing sound—one may also hear the ringing or breaking as of window panes accompanying some heavy thunder crash; the vibrations can even be perceived by the sense of touch, and sometimes by the trembling of the ground. Thus phenomena whose intensity far exceeds that producible by sound, demonstrate that other vibrations than the audible ones are also present. The very depth of the tone leads to the assumption that there are yet deeper toned pressure variations of such few vibrations that they are inaudible and the direct cause of the effects mentioned. We shall, therefore, endeavor to demonstrate these vibrations which are something quite novel in nature, as well as to complete the picture by recording the audible vibrations.

METHODS FOR RECORDING THE VIBRATIONS.

2. *Instrument I.*—Two different instruments, I and II, serve to accomplish these two purposes. The instrument, I, designed to record the longer vibrations could use a mechanical registration since there was considerable energy available and the velocities to be recorded were not too great. In its final form, I consisted of a wooden box of 210 liters capacity, having all its joints carefully sealed, and with a hexagonal aperture of more than 250 sq. cm. in one of its sides. This aperture was almost closed by a very light aluminum plate suspended by means of two long threads, so that the plate could swing freely in and out. Thus every atmospheric compression-wave falling upon the box must also compress and reduce the volume of the air within the chamber and the aluminum plate, acting as a piston, swing inwards. The reverse process was caused by a rarefaction of the air. A simple train of levers was sufficient to transmit these vibrations to a recording pen writing on the moving sheet of a chronograph. Experience with seismographs shows that the best device is the endless strip of smoked paper running over a motor-driven cylinder upon which rests the recording point of the pen arm. The band of record paper is stretched by a free roller suspended in the lower loop and set at a slight angle with the driven cylinder thus causing a lateral shifting of the record strip and a spiral record. With a slight friction it was possible to secure recording speeds of 5 to 8 mm. per second. The record was fixed by means of a shellac solution in the usual way.

3. *Standardization of instrument I.*—It would be a mistake to assume that the displacement of the pen is proportional to the variations in pressure. The inertia

[1] Author's abstract (German) of the two following papers: "Analyse des Donners," Sitzungsb., K. k. Akad. d. Wissens. IIa, Wien, 1912, **121**: 2045.
"Ueber das Wesen des Donners," ibid., IIa, 1914, **123**.
Translated from Meteorologische Zeitschrift, Braunschweig, Okt. 1914, **31**: 487–498.—C. A. jr.

due to the mass of the aluminum plate and of the air itself, the period of vibration of the whole system, the partial equalization of pressure within and without the chamber by means of the open interval around the plate, and finally friction, all these induce a delay and particularly a change in the magnitude of the pen displacement which can, of course, be computed from the measurements but are much better determined empirically. For this purpose a hole is bored in the wall of the chamber and a closed glass tube, fitting it quite closely, is inserted and pushed in or withdrawn by hand. If the stroke of this glass piston is regulated by means of collars fitted to it, and if one limits himself somewhat to producing the gentler waves, then the changes in volume produced by the piston stroke may be converted into pressure changes which may be compared with the curves simultaneously recorded by the instrument. There is here the advantage of being able to pick out only those waves of regular form and having the period of vibration simultaneously recorded. Indeed the latter primarily determines the magnification. For example, a pressure wave whose amplitude [corresponds to a pressure change] of 1 mm. mercury shows—

Time of vibration.	Deflection of recording pen.
Seconds.	*Mm.*
0.2	41
.4	79
.6	53
.8	29
1.0	20
3.1	5

Whence it appears that very rapid and very slow vibrations are least pronounced; the period of vibration of the system and consequently the strongest magnification lies in the neighborhood of 0.4 second. The conversion of the recorded vibrations is carried out by the aid of the above values. This method of standardization brings the special advantage that the numbers do not hold true in the case of the deflections produced by an infinitely long series of similar waves but, by reason of the involuntary variations in the wave lengths produced during the standardization, hold only for isolated deflections such as are significant in thunder.

4. *Instrument II.*—The second instrument, II, designed to study the sound vibrations of thunder, employs a method somewhat approaching the smoke-ring method used by Marbe (1). A graphophone horn of 57 centimeters aperture stands at right angles to the window, with its mouthpiece (reproducer end) applied laterally to a short upright chimney of less than 4 square centimeters cross section. All compression waves (Dichtewellen) that strike the large end of the horn are propagated with much magnified amplitude into the chimney and induce vibrations in a small smoky turpentine flame. The upper end of the flame, extending beyond the top of the chimney, was intercepted at about 5 mm. from the chimney top by a moving strip of telegraph paper driven at the rate of about 145 mm. per second by an electric motor. Appropriate screens caused the smoky flame to deposit a uniform band of soot when the flame was at rest; but every jump of the flame, every condensation or rarefaction of the air, caused a heavier or lighter deposit of soot so that transverse bands were deposited upon the paper strip. The measured interval between two such bands and the known speed of the paper permits the determination of the time interval between two individual successive condensations. The rough surface of the paper used held the soot so firmly that one could "fix" the important portions of the record at a later time.

The advantages of this device are: the absence of coarse inert masses, a minimum frictional effect, the possibility of expanding the time scale with a consequent more detailed analysis of the processes studied, and finally the small cost which removes any limits to the length of the record strip used (e. g., 700 meters for a thunderstorm). The only appreciable disadvantage lies in the fact that while instrument II permits qualitative observations such as the duration of vibrations, it is possible to make only rough quantitative gradations according to the intensity of the coating.

5. *Installation; Time determination.*—For a time both devices were set up and in running order in the laboratory of the K. k. Zentralanstalt für Meteorologie u. Geodynamik in Vienna. On the approach of a thunderstorm it was merely necessary to open a window, switch in the motor, and light the turpentine lamp. An important matter here, however, was the time-recording device for it was only by its aid that one could correlate the simultaneous records of the two instruments, and the contemporaneous notes on the character of the audible sound phenomena, the distance of the lightning, etc.

To secure the time record the anchor escapement, or lever, of a simple alarm clock was so modified that a single oscillation of the lever closed and opened an electric circuit, thereby making time marks alongside both the curve of instrument I and the soot band of No. II. An additional key inserted in this time circuit permits the time marks to be interrupted at any instant, thus furnishing a ready means of distinguishing them. The latter procedure was used on instrument II only when it was desired to test the speed of the paper band; otherwise the slightly confusing succession of time marks on this record was replaced by consecutively numbered little pasters stuck on the strip promptly after each thunderpeal, thereby giving ready identification of the corresponding portions of the record.

Records with instrument I were secured during the summer of 1912, and both instruments simultaneously recorded some thunderstorms during the summer of 1913. In the following pages are first discussed the results of studies of sound vibrations due to thunder, which are in part known to the ear; afterwards I consider the more violent pressure variations of somewhat longer duration which present something fundamentally new.

RESULTS OF THE RECORDS.

Sound waves.

6. *General review.*—Instrument II, in its final form, began its records with the two thunderstorms of August 6 and 12, 1913, and approximately 20 audible thunder peals. In each case the effect of the air vibrations was recorded as a pronounced rapid alternation of light and dark bands across the record paper in place of the otherwise uniform gray soot coating. The time of duration of each could be simply determined from the interval between two adjacent bands. The general appearance of the record showed that the most diverse kinds of vibra-

tions succeed one another in a thunderpeal; beginning with about 25 per second (a lower number was not so readily perceived) and ranging up to more than 100. These vibrations formed an uninterrupted series, but pronounced regularity was not to be remarked except in the later portion of the thunder; most cases showed a merry mixture of series of shorter and longer vibrations, particularly immediately after the first impact and later at the occasional pronounced intensifications. It thus appears that only individual portions of the thunder can be regarded as a "tone." The other portions are at the best but "noises," if this name is applied to the irregularity of the time intervals alone and not made to include the usually wholly arbitrary implication that one here has primarily to do with specially rapid vibrations.

Now generally irregular pressure fluctuations must change and weaken much more rapidly during their propagation than do regular fluctuations, and this is intensified as the interval shortens. If these records of thunder that has already traveled a considerable distance (in all cases I observed a marked interval between the lightning and the first sound) enable us to infer the procedures in the vicinity of the lightning path, then we here have to do with a series of very violent, irregular, pressure fluctuations taking place in particularly rapid succession; there the (klirrende, knatternde) rattling, clanking thunder has a much higher, almost metallic Klangfarbe (tone color). The appropriateness of the term "clanking" (klirrende) is shown by the experiment where the closed window was smartly struck; the apparatus then recorded vibrations that were in general quite similar to those of thunder.

The fine variations in the shades of the smoked record of instrument II unfortunately are not adapted to clear reproduction. They were therefore translated into numbers with the aid of a numbered scale of shades of black and grays, the highest numbers (plotted as ordinates) indicating the deepest blackening or the most violent pressure waves. In this way has been constructed figure 1 [omitted], which shows the translated record obtained on August 6, 1913, during the first seconds of the thunder at 2:44 p. m. In this very carefully executed twofold copying the regularities were involuntarily emphasized; however, it is clearly shown that immediately after the first somewhat slower vibrations, very rapid changes set in at once and that the same procedure takes place after the first node of the thunder.

7. *Statistical summary.*—Of course such a detailed treatment was not possible for all the cases of thunder. In its place I attempted to characterize the variations by a statistical method, by determining the duration of each thunder and then to compute the frequency of occurrence of the peals of various durations. In this way was obtained column 2 of Table 1, from the three most completely recorded thunders, the numbers of waves being grouped by equally spaced intervals of the number of vibrations per second. But one is not to assume that in speaking of the "number of vibrations per second" we ever measured a long, regular series of them. Even two successive vibrations seldom had exactly the same duration. The concept "tone" is here in mind, since this name is at times also applied to single waves.

TABLE 1.—*Distribution of frequency of rapid vibrations in thunder.*

Number of vibrations per second.	Number of waves.	Rough distribution of energy (ratios).
15–25	70	569.6
25–35	52	180.1
35–45	40	76.9
45–55	24	29.5
55–65	22	17.8
65–75	18	10.9
75–85	42	19.6
85–95	56	20.5
95–105	62	18.6
105–115	71	17.7
115–125	45	9.5
125–135	25	4.5
135–145	23	3.6
145–155	16	2.1
155–165	14	1.6
165–175	12	1.3
175–185	9	0.8
185–195	6	0.5
195–205	5	0.3

According to this table the most likely tones to hear in thunder are those with 15 to 40 vibrations per second (E, the second E below the bass clef); those of 40 to 75 are less frequent, while higher tones, 75 (D# in the bass) to 120 or A are again of frequent occurrence. Tones of yet higher vibrations, such as those usually met with in music, are again quite rare.

As only those vibrations were measured that exceeded a definite intensity, the above figures do present the distribution of intensities to a certain degree; nevertheless they are not to be regarded as an expression of the distribution of energy. Values are indeed given, and for these a wave of longer duration had the same value as one of shorter duration. If it is desired to pass to energies then the intensities are to be multiplied by the times of their duration, i. e., by the reciprocals of the vibration numbers (given in column 1); thus are secured the values in column 3 of Table 1, where the generally uniform character of the distribution gives particular emphasis to the extraordinary prominence of the longest waves with vibration numbers below the limit of sound. The manner of recording is less favorable to the registering of yet longer vibrations, and as a matter of fact the contrast is really much greater than our table can express.

Pressure vibrations of longer duration.

8. *General review.*—The whole distribution of the energy permits one to anticipate that yet slower vibrations play a large part. For various reasons these slower vibrations could not be adequately recorded by means of instrument II; but it was otherwise with instrument I, which was designed to reveal precisely this class, and which furthermore permitted quantitative determinations. As early as the summer of 1912 records of this kind had been secured, but the much more reliable standardization was not carried out until 1913, and we shall therefore restrict this discussion to the four thunderstorms at the end of July and beginning of August of that year, embracing 47 thunderpeals. Ten of the peals were vigorous enough to yield well developed records throughout.

In general the strongest pressure variations uniformly showed relatively long periods lying between 0.2 and 0.5 second with a maximum of 0.54 second. Even when they were far below they coincided with the limits of audibility,[2] points of the greatest audible loudness, the "beats" and "nodes" of the thunder indeed briefly preceded them; so that in every case the first vibrations to arrive were slow ones even though slightly later accompanied and followed by more rapid ones.

9. *Precise evaluation—Energy content.*—In the case of those 8 thunderpeals where the pen did not jump over the paper too fast (this was not altogether avoidable), the records were evaluated by measuring and computing the duration and amplitude of the strongest waves. In the case of the thunder of August 6, 2:46 p. m., all the plainly distinguishable variations were thus measured. The results of this last-mentioned case are presented in Table 2. The greatest durations of vibrations are fairly uniform according to their magnitudes; as mentioned above, they range between 0.20 and 0.54 second, and if the change were repeated regularly might be regarded as tones lying one or two octaves below the limit of audibility. On the other hand the maximum variations in pressure measured between the extreme positions are far more contrasted. The highest value of the pressure is 0.017 mm. of mercury, which is very considerably above that of the strongest sound.

TABLE 2.—*Determinations of 17 of the stronger waves of the thunder at Vienna on Aug. 6, 1913, at 2:46 p. m.*

Duration of vibration.	Amount of vibration.	Intensity of wave.	Energy of wave (internal).
Secs.	*Mm.* of Hg.	*Erg/cm.²sec.*	*Erg/cm.²*
0.32	0.017	1.63	0.522
.24	.005	0.11	.026
.38	.004	.09	.034
.16	.003	.06	.009
.18	.006	.18	.032
.20	.004	.08	.015
0.22	0.002	0.01	0.003
.22	.004	.11	.024
.18	.013	.92	.166
.34	.014	1.02	.347
.16	.003	0.06	.009
0.24	0.003	0.05	0.013
.38	.002	.01	.005
.24	.003	.05	.013
.22	.004	.09	.019
.14	.004	.08	.011
.28	.003	.04	.025

One can now calculate by means of the pressure changes, the intensity, I, of the sound, i. e. the amount of energy passing in 1 second through 1 square centimeter of a plane perpendicular to the direction of propagation of the sound. In the formula (1)

$$I = \frac{\rho c^3}{2\kappa^2}\delta'^2$$

$$= 0.304 \times 10^{10}\delta^2$$

the velocity of sound, c, at 18°C. and the mean pressure 743 mm., was taken as 342.8 meters per second and the specific gravity, ρ, as 0.001186. The ratio of the specific heat of air, κ, is put at 1.402; the pressure amplitude δ' in the first expression is in absolute measure, δ in the second expression is measured in millimeters of mercury. Thus are derived for this one thunder, the figures given in column 3 of Table 2, and multiplying these by the duration in time of each individual vibration they are converted into the energy-amounts given in the last column. It is now possible to compute the total energy embodied in the pressure variations of this thunder peal. By adding the values in column 4 there results 1.27 erg/cm² for the evaluated vibrations which occupied a time interval of 4.1 seconds. Now if it is assumed that the total duration of the thunder was 13 seconds, which is probably close to the actual facts, and that the mean intensity during the missing 8.9 seconds which was too small to measure, was approximately 0.01 erg/cm²sec., then the total energy amounts to about 1.4 erg/cm.² Further, suppose that the origin of the disturbance had the form of a point and was 5 km. (which is too far) distant from the point of observation then, disregarding losses due to friction and other causes, the *total energy* of the thunder amounted to 22,000 meter-kilograms (2).

10. *Comparison with the energy of lightning. Energy loss.*—For comparison we may deduce the approximate value of the energy of lightning. Riecke gives 95 coulombs as the quantity of electricity transported in the stronger discharges; the tension is probably overestimated at 10^9 volts; whence the energy is approximately 10^{10} meter-kilograms, a value quite disproportionately in excess of that of the computed energy of thunder.

Although the necessity of making arbitrary assumptions in the calculations greatly impairs the reliability of both values, neverthless it is quite certain that their magnitudes are widely different; hence it is certain that at a short distance away only the smallest fraction of the energy of lightning is still present in the form of pressure vibrations.

There are two plausible causes for this perhaps somewhat unexpected result: (1) A considerable amount of energy is consumed in the nonmechanical forms of heat and light at the time of the discharge; (2) the propagation of such pressure vibrations, both much greater than those of ordinary sound and also of irregular character, causes a considerable loss in intensity. But this second cause must also find expression in the fact that the individual thunder peals, which generally originate at different widely separated lightning bolts, show corresponding mutual departures. These facts are revealed much better by the original records than by the evaluated curves and tables. Figure 2 [omitted] shows approximately the first four seconds at the beginnings of three thunder records. Only one of them starts off at once with one of the most pronounced pressure vibrations, in one case the vibrations increase more gradually to the maximum. But one may distinguish similar differences in the thunder sounds that come to our ears: Some begin at once with a heavy crash after which the intensity decreases (we need not here consider the cases of occasional later temporary increase), others increase gradually. This feature is so pronounced that we may at once classify thunder into *Group A*, the sudden crash, and *Group B*, the gradually developed crash. Figure 2 [omitted], shows that these are essential differences. The strongest vibrations in the former group show a single wave (impulse) succeeded by others that are scarcely worth mentioning; the latter group have, as a rule, a rather regular series of waves whose amplitudes show a steplike increase and then a dying out. Upon computing the mean maximum amplitude of vibration of the more accurately evaluated four peals of Group A it is found to be 0.43 erg/cm² and that of the four in Group B is 0.14 erg/cm² sec. Considering the known fact that the thunder in the vicinity of the flash always sets in with the heaviest crash so that the observed interval

[2] In extreme cases the limit of audibility is about 0.05 second duration of vibration, yet in such cases the hearing is regarded as very sensitive.

between the first noise and the heaviest crash must develop during the propagation of the sound, one must conclude that the main vibration becomes separated from the beginning of the thunder after a considerable path has been traversed. One can also cite ear observations in this connection. Thus it appears that the thunders of Group A are generally to be considered the original, earlier vibrations; after traveling some distance they would transform themselves into those of Group B.

11. *Similarity with explosion waves.*—It follows from the preceding that any conclusions regarding the origin of thunder will be based, by preference, on the facts relating to Group A. A more detailed comparison of these records leads to the first and most surprising result that the strongest deflection always indicates a rarefaction. It is preceded by only a very brief jog that might indicate a compression. The empirical calibration, as well as a little reflection, indicates that in the apparatus the magnification of vibrations close to the period proper to the system is considerably greater than that of other vibrations, and that in the case of vibrations of brief duration the magnification is quite small. It is, therefore, not altogether out of the question that the amount of the actual condensation represented by the first small jog should exceed the rarefaction of the succeeding vibration.

It is certain that none of the following deflections even approximates in intensity that of the maximum; perhaps then the latter with its antecedent compression is to be regarded as a kind of isolated wave (Einzelwelle). This wave always introduces the vibrations in much the same manner, and is followed by the irregular deflections.

Experiments had already revealed a kind of condensation wave that bears much the same characteristics, viz, the percussion or explosion wave. When a compression or rarefaction of the air takes place with extraordinarily great speed (suddenly) at one point, there arise differences in density that no longer can be called small as compared to normal pressure, even when they have traveled considerable distances. In such a case it is not permissible to disregard the usual theory of the propagation of sound; with increasing contrast in density the velocity of propagation considerably exceeds that of sound. Here the parts of the wave having the greatest pressures advance more rapidly than those of lesser pressure and soon are in the van; so there arises here something approximating a discontinuity, a sudden jump in density. The instant this condition is established the front becomes a source of wave motion which, according to Tumlirz (**3**), who has further developed these points along the lines of the Riemann theory, travels backward as does a reflection and thus consumes some of the intensity of the percussion wave. In this way the density contrasts in the latter finally become so far reduced that it travels only with the velocity of sound and loses its special characteristics.

Experiments with release by explosions, cases where such waves may be observed and studied to special advantage,[3] showed that here the total amount of energy expended is of secondary importance, while the prime essential is the manner of release, its suddenness.

12. *Phenomena due to spark waves; explanation of thunder.*—No doubt the electric spark belongs to the quickest phenomena that we know. It generates tremendous compressions along its path, as shown, among others, by H. Mache & E. Haschek (**4**), who found that a pressure of 64 atmospheres was developed in a spark gap of 3 millimeters, although the pressure was simultaneously increased by the presence of subdivided electrode material. For this reason E. Mach (**5**) naturally found the spark a simple method for studying the phenomena in point by the aid of the Schlieren and interference methods. His presentation reveals all the above essential phenomena, the quick rise in pressure at the beginning of the wave, the following slower rarefaction, and the appearance of superposed waves after the highest pressure has passed. Wolff's experiments in explosions on a grand scale show similar features (**6**).

Let us now imagine the tiny spark magnified to the tremendous dimensions of a lightning flash, all the sequential phenomena will also show a very considerable magnification. The extraordinarily great electric repulsion between the similarly charged particles in the lightning path seems to be the principal cause of a sudden very strong rise in pressure. Here heating seems to play but a small part, and electrostriction or deformation due to electric stress would act in the opposite direction. A percussion wave due to this sudden strong pressure rise advances from it in every direction in the form of something near a cylinder wave. Primarily the total energy of the alternations in density is united in this wave; gradually, however, waves set out backward from it. The original simple detonation, which Lummer (**7**) thinks is the form in which we hear an explosion wave, grows weaker while variations in density of longer duration follow, the rumbling sets in. In the course of time the energy content of the detonation is no longer essentially differentiated from the more usual sound waves, the primary vibration no longer plays a special rôle and on occasion may become quite lost among the various disturbing influences or even previously change its form, so that it is introduced by a rarefaction. Though the isolated waves die out, there long persist all the accidentally formed regular wave series. Finally, the latter alone are essentially in existence.

Other details of the records agree with the above deduction. Short waves set in, in Group A, after the first strong deflections; furthermore, instrument II yields a record here that agrees essentially with that produced by bursting paper bags. Regular series of waves occur mostly in the later portions of the thunder.

13. *Explanation of the longer duration and the repeated "beats."*—The increasing breadth of the density changes due to an explosion wave may explain the increasing duration of the thunder; but some other explanation must be sought for the repeated "beats" or "nodes" that often occur several times in succession in the same peal. One is here involuntarily led to the idea—perhaps by the longer duration of the thunder—that every point of the spark path is to be regarded as an independent source of disturbance, whence the first sounds to reach the ear are from the points nearest thereto and succeeding sounds are from increasingly distant sources. Aside from the consideration that according to this theory the lightnings nearest the point of observation would generally give the longest enduring thunder, which is contrary to our experience, the laws of physics would require that in such a case the thunder would be heard as a single simple sound, because the disturbances along the whole of the spark path are practically simultaneous and set free in the same form. A comparison with the salvo from a firing squad disregards the essential components just mentioned, and therefore leads to a quite false conclusion.

Since the idea of uniform disturbance along the whole spark path does not support the explanation of the longer duration of the thunder, then the possibility of the occurrence of a finite series of intensifications or beats is the logical result from the fact that we have to do with

[3] The sudden production of a rarefaction, such as results from the sudden collapse of an exhausted glass sphere, will produce the corresponding phenomenon with a rarefaction in place of a condensation.

neither a straight-line path nor a precisely simultaneous release at all points along it. Experiments with sparks following sharply bent paths (8) showed that the distinct wave series originated by the different sections of the spark path show but imperfect mutual fusion, and in part intersect one another even when they have become very weak. The same may be predicated of sharply-bent lightning flashes, which after all are seen not to be so very frequent if one makes proper allowance for the deceptive appearances due to perspective shifting. The second set of circumstances also tends to produce these more or less independent centers of disturbance separated by longer intervals, since experiments here also have shown that the same spark produces quite different effects according to the different conditions and resistances encountered along its path. Thus points that have already been traversed by the predischarge (preliminary) offer better conductivity than others.

Probably the most important rôle is that of the currents of the atmosphere. There is no essential difference between their deflective and other effects upon explosion waves and ordinary sound waves. The greater the distance between the source and the observer, the more diverse are the paths to the observer traveled by the different parts of the wave, the longer does the thunder seem to endure, and the larger the number of "beats" (Schläge) it shows. These experiences are in agreement with the results J. N. Dorr (9) has obtained from the study of the effects of the great explosion in the quarries at Wiener-Neustadt. He found that as it traveled the original simple detonation broke up into a series of separate sounds that were in part of a different character, viz, rumblings.

14. *Relationship to the intermittent character of the lightning discharge.*—B. Walter was the first to accurately analyze the phenomenon of multiple successive partial discharges along the same lightning path, but I would not explain the multiple beats of thunder by this phenomenon. It is true that they succeed one another very rapidly at intervals which at first are the same as those of the shorter intervals revealed by instrument II. Perhaps this does enable them to have some influence upon the sound phenomenon, for it is readily conceivable that their somewhat pronounced periodicity is of mechanical origin. Thus, supposing all the air particles are hurled apart by the first partial discharge, then in the next instant they will swing back to their positions in the spark path thereby generating a condensation that of course causes a new rarefaction which greatly assists the further discharge through the same channel, of the electricity that had accumulated in the interim. This process may be repeated until the supply of electricity becomes too small. Now every time this occurs compression waves are sent out and all in all these may well produce upon the observer the impression of a more or less regular series. In counting up the time intervals of the partial discharges recorded in Walter's unfortunately very small number of photographs, I found 5 cases which would correspond to 15–40 vibrations per second, 4 cases between 40 and 65, 2 cases between 65 and 90, and 1 case of 90–115 vibrations. This distribution reminds one so strongly of that in the sound waves from the thunder revealed by instrument II (see Table 1) that one is inclined to see here a fundamental relationship. It is simply necessary to imagine that at least one portion of the waves separating from the discontinuity, originated simultaneously at the beginning and even favored the discharges that threw off the others. E. Mach has shown that explosion waves may carry others superimposed upon them.

SUMMARY.

The records made by appropriately designed recording instruments (§§1–5) show that thunder presents frequent alternations of pressure vibrations of very various durations; but these are so irregular (§6) that one can not here speak of tones, although the time interval separating two vibrations is partly short enough when they come regularly to make tones of a rattling, clanging kind whose records are quite similar to those of the clanking windowpane. The evaluation of the records of three thunderpeals (§7) revealed that intervals of 1/75 to 1/120 second were somewhat more frequent and that at first longer intervals were of less frequency, until coming to those above 1/40 second (tones lower than E), there was an increased frequency that multiplied as one approached the vibrations too long to be audible.

The essential constituent of thunder, however, were the yet longer vibrations, certainly far below the limits of audibility, which were rather violent pressure variations (the highest observed duration being more than one-half second) that were accompanied by the "beats" or "nodes" in the thunder (§8). In one case the deflections of these pressure variations amounted to 0.017 mm. Hg., or considerably more than that due to the highest sound impulse. The determination of the total energy content of the strongest recorded thunder (§10) showed it was certainly a very insignificant fraction—less than 0.000 01—of the energy of lightning. One must therefore conclude that the latter is mostly consumed by other forms of energy, such as heat and light.

Thunderpeals whose strength justifies the assumption that they have not traveled very great distances are characterized by a single initial maximum deflection of rarefaction, in no case preceded by more than a very brief condensation (§10). Their form closely simulates that of the percussion or explosion waves radiating from very suddenly produced condensations or rarefactions (§11). Their velocity of propagation is at first much greater than that of sound, but approaches this as the intensity of the density disturbance rapidly decreases on account of the retrogressive waves sent out from the discontinuity itself.

Laboratory experiments show that such explosion waves arise at an electric spark gap, where it has been possible to demonstrate there exists an extraordinarily marked pressure rise. Their properties are thus all the more evident in thunder. Thus are to be explained (§§12, 13) the rapid decrease in intensity, the change in tone color, while the irregular air currents are responsible for the increasing duration as the point of origin of the thunder retreats and for the recurring "beats."

The isolated (ausgelösten) waves are most probably due to the intermittent discharges that occur so frequently in lightning (§14).

NOTES AND REFERENCES.

(1) **Marbe** *in* Phys. Ztschr., 1906, **7**: 543.
Marbe & Seddig, *in* Annalen d. Phys., (4) 1909, **30**: 579.

(2) The magnitude of this energy when considered as energy of sound is shown by the following comparison. Webster estimates that that 10^7 trumpeters can generate a tone of 1 HP. Thus the power of a trumpeter at the distance of 1 meter is still 0.02 erg/cm²sec.; i. e., even less than 1/300 of the first wave as measured in Table 2. If, therefore, it were desired to equal the total energy-content of the thunder by means of trumpeting we would need 2×10^8 trumpeters blowing in a uniformly sustained manner for 13 seconds.

(3) **Riemann-Weber.** Partielle Differentialgleichungen der mathematischen Physik.

Tumlirz, *in* "Lotos," Jahrb. f. Naturw., Prag, 1880, **29**; *and* Sitzungsb., K. Akad. d. Wissensch., Abt. IIa, Wien, 1887, **95**: 367.

(4) **Mache, H.** Ueber den Druck in Gasen unter dem Einfluss starker elektromotorischer Kräfte. Sitzungsb., K. Akad. d. Wissensch. Abt. IIa, Wien, 1898, **107**: 708.

Haschek, E. & Mache, H. Ueber den Druck im Funken. ibid., 1898, **107**; Annalen d. Physik (Wied.), N. F., 1899, **68**: 740.

(5) **Mach, E. & Weltrubsky, J. v.** Ueber die Formen von Funkenwellen. Sitzungsb., K. Akad. d. Wissensch., Wien, 1878, **78**: 551.

(6) **Wolff** *in* Annalen d. Physik (Wied.), N. F., 1899, **69**: 329.

(7) **Lummer.** Ueber die Theorie des Knalles. Schlesischen Gesells. f. vaterl. Kultur, II. Abt., 1905, **83**. Jhrb., p. 2.

(8) **Mach, E. & Gruss, G.** Optische Untersuchung der Funkenwellen. Sitzungsb., K. Akad. d. Wissens., Abt.IIa, Wien, 1878, **78**: 479.

(9) **Dörr, J. N.** Ueber die Fernwirkung der Explosion am Steinfelde bei Wiener-Neustadt (1912, Juni 7). Sitzungsb., K. Akad. d. Wissens., Kl. IIa, Wien, 1913, **122**: 1683.

(10) **Walter, B.** *in* Phys. Ztschr., 1902,**3**:168; *also* Hamburger wissens. Anstalten, Jhrb. 1903, **20**.

THE PLACE OF FORESTRY AMONG NATURAL SCIENCES.[1]

By HENRY S. GRAVES, Chief, United States Forest Service.

[Extracts from an address delivered before the Washington Academy of Sciences, Dec. 3, 1914.]

Forestry as a natural science deals with the forest as a community in which the individual trees influence one another and also influence the character and life of the community itself. As a community the forest has individual character and form. It has a definite life history; it grows, develops, matures, and propagates itself. Its form, development, and final total product may be modified by external influences. By abuse it may be greatly injured, and the forest as a living entity may even be destroyed. It responds equally to care, and may be so molded by skillful treatment as to produce a high quality of product and in greater amount and in a shorter time than if left to nature. The life history of this forest community varies according to the species composing it, the density of the stand, the manner in which the trees of different ages are grouped, the climatic and soil factors which affect the vigor and growth of the individual trees. The simplest form of a forest community is that composed of trees of one species and all of the same age. When several species and trees of different ages occupy the same ground, the form is more complex, the crowns overlapping and the roots occupying different layers of the soil. Thus, for instance, when the ground is occupied with a mixed stand of Douglas fir and hemlock, the former requiring more light occupies the upper story, and because of its deeper root system extends to the lower-lying strata of the soil. The hemlock, on the other hand, which is capable of growing under shade, occupies the under story, and having shallow roots utilizes largely the top soil. * * *

In a forest there is altogether a different climate, a different soil, and a different ground cover than outside of it. A forest cover does not allow all the precipitation that falls over it to reach the ground. Part of the precipitation remains on the crowns and is later evaporated back into the air. Another part, through openings in the cover, reaches the ground, while a third part runs down along the trunks to the base of the trees. Many and exact measurements have demonstrated that a forest cover intercepts from 15 to 80 per cent of precipitation, according to the species of trees, density of the stand, age of the forest, and other factors. Thus pine forests of the North intercept only about 20 per cent, spruce about 40 per cent, and fir nearly 60 per cent of the total precipitation that falls in the open. The amount that runs off along the trunks in some species is very small—less than 1 per cent. In others—for instance, beech—it is 5 per cent. Thus if a certain locality receives 50 inches of rain, the ground under the forest will receive only 40, 30, or 20 inches. Thus 10, 20, and 30 inches will be withdrawn from the total circulation of moisture over the area occupied by the forest. The forest cover, besides preventing all of the precipitation from reaching the ground, similarly keeps out light, heat, and wind. Under a forest cover, therefore, there is altogether a different heat and light climate and a different relative humidity than in the open. * * *

The effect which trees in a stand have upon each other is not confined merely to changes in their external form and growth; it extends also to their internal structure. The specific gravity of the wood, its composition, and the anatomical structure which determines its specific gravity differ in the same species and on the same soil and in the same climate, according to the position which the tree occupies in the stand. Thus in a 100-year-old stand of spruce and fir the specific gravity of wood is greatest in trees of the third crown class (intermediate trees). The ratio of the thick wall portion of the annual ring to the thin wall of the spring wood is also different in trees of different crown classes. The difference in the size of the tracheids, in trees of different crown classes, may be so great that in one tracheid of a dominant tree there may be placed three tracheid cells of a suppressed tree. The amount of lignin per unit of weight is greater in dominant trees than in suppressed trees. * * *

Forestry, unlike horticulture or agriculture, deals with wild plants scarcely modified by cultivation. Trees are also long-lived plants; from the origin of a forest stand to its maturity there may pass more than a century. Foresters therefore operate over long periods of time. They must also deal with vast areas; the soil under the forest is as a rule unchanged by cultivation, and most of the cultural operations applicable in arboriculture or agriculture are entirely impracticable in forestry. Forests, therefore, are largely the product of nature, the result of the free play of natural forces. Since the foresters had to deal with natural plants which grew under natural conditions, they early learned to study and use the natural forces affecting forest growth. In nature the least change in the topography, exposure, or depth of soil, etc., means a change in the composition of the forest, in its density, in the character of the ground cover, and so on. As a result of his observations the forester has developed definite laws of forest distribution. The forests in the different regions of the country have been divided into natural types with corresponding types of climate and site. These natural forest types, which, by the way, were also developed long before the modern conception of plant formations came to light, have been laid at the foundation of nearly all of the practical work in the woods. A forest type became the silvicultural unit, which has the same physical conditions of growth throughout, and therefore requires the same method of treatment. The manner of growth and the method of natural regeneration, once developed for a forest type, hold true for the same type no matter where it occurs.

After the relation between a certain natural type of forest and the climate and topography of a region has been established, the forest growth becomes the living expression of the climatic and physical factors of the locality. Similarly, with a given type of climate and locality it is possible for the forester to conceive the type of forest which would grow there naturally. The forester, therefore, may speak of the climate of the beech forest, of the Engelmann spruce forest, of the yellow-pine forest. Thus, if in China, which may lack weather observations, we find a beech forest similar to one found

[1] Reprinted from Journal, Wash. Acad. Sci., Jan. 19, 1915, 5:41-56.

in northern New York, we can be fairly certain of the climatic similarities of the two regions. More than that, a type of virgin forest growth may serve as a better indication of the climate of a particular locality than meteorological records covering a short number of years. A forest which has grown on the same ground for many generations is the result not of any exceptional climatic cycle, but is the product of the average climatic conditions that have prevailed in that region for a long time. It expresses not only the result of one single climatic factor, but is the product of all the climatic and physical factors together. Similarly, the use of the natural forest types for determining the potential capacity of the land occupied by them for different purposes, is becoming more and more appreciated. When the climatic characteristics of a certain type of forest, for instance, those of Engelmann spruce in the Rocky Mountains, is thoroughly established, the potential capacity of the land occupied by it for agriculture, grazing, or other purposes is also largely determined.

Observations of the effect of climate upon forest growth naturally brought out facts with regard to the effect of forests upon climate, soil, and other physical factors and led to the development of a special branch of meteorology, known as forest meteorology, in which the foresters have taken a prominent part. While there are some phases in forest meteorology which still allow room for disagreement, some relationships established by foresters are widely accepted. One of these is the effect which forests have upon local climate, especially that of the area they occupy and of contiguous areas. Every farmer who plants a windbreak knows and takes advantage of this influence. Another relation is that between the forest and the circulation of water on and in the ground, a relation which plays such an important part in the regimen of streams. Still a third one, as yet beyond the possibility of absolute proof, is the effect of forests in level countries, in the path of prevailing winds, upon the humidity and temperature of far-distant regions lying in their lee. * * *

WHY SOME WINTERS ARE WARM AND OTHERS COLD IN THE EASTERN UNITED STATES.

By W. J. HUMPHREYS, Professor of Meteorological Physics.

[Dated Weather Bureau, Washington, Feb. 1, 1915.]

INTRODUCTION.

As every one knows, no two winters are exactly alike. Even a short memory will convince one living in the eastern United States that here some winters are much colder than the average while others are exceptionally mild. Of course, many other places experience similar differences in the severity, or, if one prefers, geniality of their seasons, and to each there necessarily belongs an interesting study of how these differences occur and why. In the present paper, however, only exceptional winters in the eastern United States will be considered.

LIST OF ABNORMAL WINTERS.

An examination of the climatological records shows that beginning with December, 1880, the earliest date for which we have sufficient and convenient data for the present study, the eastern United States has had a number both of exceptionally mild and of exceedingly cold winter months. The more pronounced of these are listed in Table 1, in which the numbers give, roughly, each the average temperature departure for the month in question, over the eastern United States, from the corresponding normal.

TABLE 1.—*Excessive monthly temperature departures in the eastern United States.*

Winters.	December.	January.	February.	March.
	°F.	°F.	°F.	°F.
1880–81	−4	−4		−3
1881–82	5	4	5	
1883–84			6	
1884–85			−6	−6
1885–86		−4		
1886–87	−5			
1887–88				−4
1889–90	7	9	9	
1890–91			6	
1891–92	6			
1892–93		−8		
1893–94		4		
1894–95			−7	
1897–98				5
1900–1901			−5	
1903–04	−5	−5	−5	
1904–05	−4		−7	
1908–09			4	
1911–12	5	−5		
1912–13	4	9		5

PREPONDERANCE OF LOCAL OVER GENERAL CAUSES.

If we omit isolated months and consider only entire winter seasons, it will appear that usually the temperature departure of the eastern United States has been of the same sign as that of the whole world, which in turn seems to depend upon the combined influence of sun spots and volcanic dust (1). This general agreement shown in Table 2, it should be remembered, is between the annual temperature departure of the world as a whole and the winter temperature departure of only the eastern United States. Therefore, agreements and disagreements in their signs, since the periods are not the same and since the local seasonal departure often is from 10 to 20 fold that of the world-wide annual departure, probably have but little meaning. Nevertheless, if the number of cases were sufficiently large there probably would be rather more instances where the signs of the departures were the same than where they were different; hence, though the period covered is too short satisfactorily to test even this point, it seems only fair to give the comparison table for whatever, if anything, it may be worth.

TABLE 2.—*Comparison of seasonal local (winter, eastern United States) and annual world-wide temperature departures.*

Date.	Winter, eastern United States.	Year, world.	Comparison.
1880–81	Cold	Warm	Disagreement.
1881–82	Warm	do	Agreement.
1884–85	Cold	Cold	Do.
1889–90	Warm	Warm	Do.
1903–04	Cold	Cold	Do.
1912–13	Warm	Insufficient data.	(?).

On its face this table indicates decidedly more agreements than disagreements, but, as already stated, the local winter temperature departures under consideration are so many times greater than the world-wide annual departures that the causes of the latter, though, of course, having their influence, clearly can not be the chief cause of the former. Neither do the former, pertaining to but

a single season and covering only a small part of the globe, often determine the character or sign of the latter, though necessarily they always affect its magnitude.

Presumably, indeed, there are a number of unequal and constantly varying factors that contribute, each its share, to the final results under discussion, namely, the establishment of abnormal winter temperatures, whether high or low, in the eastern United States.

RELATION OF PRESSURE DISTRIBUTION OVER THE NORTH ATLANTIC TO THE AVERAGE WINTER TEMPERATURE OVER THE EASTERN UNITED STATES.

Of the several causes, however, that control the winter temperatures of the eastern United States, *the magnitude and distribution of the barometric pressure over the north Atlantic Ocean*, through their influence on the direction and velocity of the winds and on the course, intensity, and nature of the moving storms, certainly are among the most important—in many cases probably the most important. In so general a form, however, this statement contains nothing new. At most it only delimits an important example of the climatological influence of the positions and intensities of what Teisserenc de Bort has aptly called "great centers of action," an influence first discussed at length, especially with reference to European winters, by Hoffmeyer (2) and later in greater detail and with wider application by Teisserenc de Bort (3). The partial dependence of American temperatures upon Atlantic pressures has also long been recognized by officials of the United States Weather Bureau (4).

This particular temperature-pressure relation, therefore, is well known to meteorologists, and constantly kept in mind by the American forecasters. Nevertheless its importance, both to the science of meteorology and to the art of forecasting, is sufficiently great to justify the threefold purpose of the present paper, namely:

(*a*) To bring together for study and convenient comparison the average pressure maps of the north Atlantic for all winter months of abnormal temperature departures in the eastern United States, since and including December, 1880, the earliest date for which such maps are conveniently available.

(*b*) To describe what seems to be a logical reason *why* the pressure distribution and its changes, especially in the important region of the Bermudas, should be what they are.

(*c*) To designate certain particular data which, if they should prove available, might logically be used as the basis for such general long-range (week, month, season) forecasts for the eastern United States as "Severe," "Normal," "Mild."

To facilitate as far as possible the study of the relation of the winter temperatures of the eastern United States to the distribution of barometric pressure over the north Atlantic Ocean, the temperature departure and pressure charts (monthly averages in each case) are given [1] for all the months listed in Table 1. Charts 1–17 (92–108), arranged chronologically, pertain to the cold months. Similarly, charts 18–33 (109–124), also arranged chronologically, pertain to the warm months. The temperature charts are taken from Bulletin "U" of the United States Weather Bureau (to and including the winter of 1908–9) and from the MONTHLY WEATHER REVIEW. The pressure charts from December, 1880, to February, 1905, inclusive, are copied from the best, though not generally available, weather maps of the North Atlantic (5), published jointly by the Meteorological Institute of Denmark and the German "Seewarte." The later pressure charts, those pertaining to 1909, 1911, 1912, and 1913, years for which the Danish-German charts have not yet been published, were prepared for use in this study by Frederick A. Young, of the Climatological Division of the United States Weather Bureau, to whom I wish to express my thanks and appreciation for the excellent manner in which he has carried to completion so long and so tedious a piece of work. The pressure normals were also supplied by the United States Weather Bureau, using all the best available data down to about the end of 1912.

Even a cursory examination of these pressure charts, will show that, while no two are exactly alike, those that pertain to the months of abnormally low temperatures in the eastern United States, the "cold" charts, as I shall call them, are characterized in general by an easterly displacement or intensification of the "Azores high," and the absence of any distinct "high" in the neighborhood of the Bermudas; by a strong "low" in the general region of the Newfoundland banks; or, occasionally, by both conditions.

On the other hand, the "warm" charts show a marked tendency to westward shifting of the "Azores high," and even to the development and greater or less persistence of an independent "high" in the region of the Bermudas.

The most conspicuous difference, then, between the "warm" and the "cold" type of charts appears to be in the pressure distribution along the "belt of highs." I shall, therefore, consider each type separately in its relation to this belt, but the individual charts will not be described.

Cold type.—When there is only one absolute high, or only one peak on this pressure ridge, at or east of its normal position, the temperature of the eastern United States is likely, in the wintertime, to be unusually low. (See charts 1–17.) The reason for this is obvious: That portion of the circulation about this "high" that involves warm air or southerly winds, the circulation to the west of the center of the area of high pressure, is all completed on the ocean itself. None of the warm southerly winds involved in this circulation crosses the Atlantic coast onto or over the American continent. Hence the normal westerly and northwesterly winter winds have an entirely free passage to and even far out onto the Atlantic, and in this way the whole of the eastern United States is given at such times a distinctly continental or cold (being winter) climate. The same general type of wind movement across the continent and out onto the ocean, with, during the winter, accompanying low temperatures, is permitted, or, rather, forced by a quasi stationary and well developed "low" in the neighborhood of the Newfoundland banks, and that, too, in a measure, independent of the pressure distribution along the high-pressure belt. (See chart W. J. H. 11.)

In short, that pressure distribution, whatever it may be, that causes the winds persistently to blow across the eastern United States from the interior of the continent out onto the ocean, gives to it a continental climate, and, therefore, in the winter, abnormally low temperatures. The wind roses and the isobars of the chart for January, 1912 (W. J. H., 17), illustrate the above explanations.

Warm type.—Whenever the Atlantic section of the high-pressure belt develops, and for a considerable time

[1] These charts, designated W. J. H. 1–W. J. H. 35, will be found at the end of this issue of the Review, numbered also consecutively from XLII-92 to XLII-126.

maintains, a Bermuda "high," whether independent of or in conjunction with an Azores "high;" and whenever what might be regarded as the permanent Azores "high" exists alone, but strongly displaced toward the west, the anticyclonic circulation thus established is quite likely to extend from warmer portions of the Atlantic Ocean out onto and over the eastern United States. Thus the normal storms are shunted farther north and this part of the country is given a distinctly marine climate, and, therefore, in the winter time, an abnormally high temperature. A good illustration of this action is shown by the wind roses and isobars for January, 1913 (W. J. H. 32).

It seems, then, that some winters are warm in the eastern United States and others cold because this part of the world has sometimes a more or less marine climate and at others a distinct continental climate. And the chief factors in determining this, in turn, in making the climate in question marine or continental, in giving on- or off-shore winds, are the positions and intensities of the Atlantic anticyclones, or the locations and magnitudes of the pressure peaks along the north Atlantic high-pressure ridge.

But this answer leads to still other and, if it is substantially correct, very important questions, namely: What causes these peaks or absolute "highs"? Why does the Bermuda "high" so persist of some winters and so seldom form, or when formed so quickly disappear, of others?

The first of these questions is answerable through a consideration of the "belt of highs," and this in turn suggests the probable answer to the second question.

"Belt of highs."—As is well known, the winds between the latitudes 30° N. and 30° S., roughly, blow more or less directly from east to west. Similarly the winds of higher latitudes in each hemisphere generally cross the meridians from west to east. Now, the equatorial bulge of the earth is just such that an object at rest on the surface of the ocean has no tendency to move either north or south, or, for that matter, in any other horizontal direction. In short, the ocean surface is a gravitational equipotential surface. If the earth should rotate more rapidly its equipotential surface (substantially its ocean surface) would become more bulged; if less rapidly, less bulged. Hence, an object moving from west to east finds the present surface insufficiently bulged to permit of its equilibrium and it therefore tends to climb up toward the equator. Similarly, an object moving in the opposite direction, or from east to west, is also out of equilibrium; it finds the earth too much bulged and consequently tends to slide down toward the nearest pole. From this it obviously follows that the winds from the west toward the east—that is, in general, the winds of higher latitudes than about 30° north and south—tend to climb up toward the equator, while the winds from the east toward the west, or those between approximately these latitudes, tend to slide down toward the nearest pole. Hence along the boundaries between the eastward and the westward winds, or along, roughly, the latitudes of 30° N. and 30° S., there necessarily are belts of dynamically produced and dynamically sustained high pressure.

The equatorial deflection of an eastward-moving object and the polar deflection of a westward-moving one are indeed but special cases of the well-known general law, readily found by a little analysis, that an object moving over the surface of the earth is always, whatever its horizontal direction, deflected to the right in the Northern Hemisphere and to the left in the Southern.

The numerical value of this force f, acting on the mass m, whose horizontal velocity is u at the latitude ϕ, is given by the equation

$$f = 2m\omega u \sin\phi$$

in which ω is the angular velocity of the earth.[2]

"Permanent highs."—The northern high-pressure ridge has two distinct peaks and the southern ridge three, which together are known as the permanent highs. Two are on the Pacific Ocean, one just west of southern California, the other near the coast of Chile; two on the Atlantic Ocean, near Morocco and southern Africa, respectively; and one on the Indian Ocean, about half way between southern Africa and Australia. In every case they occur where, or, rather, for reasons that will not be gone into here, just west of where the surface water, and therefore the air over it, has a lower temperature than has that either to the west or to the east. That is, they occur in every case where and only where cold ocean currents cross the belts of high pressure, and obviously result from the superposition of a thermal contraction upon the existing mechanical squeeze (6).

It is well known from sounding balloon records that anything like a long-continued change in the surface temperature is accompanied by only a little less temperature change of the atmosphere up to great altitudes—probably as far as the air has any appreciable density. Hence, above oceanic areas also, especially if, as in the cases under discussion, these be anticyclonic centers and therefore regions of sluggish air movement, we should expect the temperature to follow, in general, that of the surface water below. Hence, a decrease of 1°C. in the surface temperature should increase the density of the air above by roughly one part in 300 to 350, and the barometric pressure by from 2 mm. to 2.5 mm. But in the regions of the permanent highs, according to Buchan's charts, the temperature of the surface air ranges anywhere from 1°C. to 3°C., roughly, below that on the same latitude either east or west. Hence, we might expect at these places barometric peaks extending approximately from 2 mm. to 6 mm. above the average height of the general pressure ridge, and this indeed is the order of their normal heights.

The Bermuda "high."—As we have seen, all five of the so-called permanent "highs" are on the belts of high pressure and result from the local addition of a thermal contraction to an existing extensive belt of mechanical compression. Hence, the possibility suggests itself that the often-formed and at times quasi-permanent Bermuda "high," since it, too, is located on one of the barometric ridges, may also owe its origin to the crossing of this ridge by a belt of water whose surface temperature is lower than that either to the east or to the west; in short, that it, too, like each of the permanent "highs,"

[2] Lest the terms of this equation should be misunderstood, it may be worth while to explain them.

If the units involved are the centimeter, the gram, and the second, then:

f = dynes. A dyne is that force which gives to a gram of matter, entirely free to move, an acceleration of 1 centimeter per second per second. That is, during each second of continuous application it increases the velocity of the gram, in the direction of application, by 1 centimeter per second. A simple conception of the dyne is this: It is the weight of a gram divided by the numerical value of the local acceleration of gravity, or, approximately, it is the one 980th part of the weight of a gram.

m = number of grams in question, moving as a single unit.

ω = angular velocity of the earth's rotation measured in radians per second. Numerically,

$$= \frac{2\pi}{\text{seconds per siderial day}} = \frac{2\pi}{86{,}146}$$

u = velocity in terms of centimeters per second.

$\sin\phi$ = natural sine of the angle of latitude.

may be caused by a minimum surface temperature (giving maximum air density) along the barometric ridge on which it is situated.

Indeed, the idea that the Bermuda "high," especially when at all persistent, may be produced in the manner suggested seems to be strongly supported by charts 34 and 35 (125 and 126) that give, respectively, the February and May surface temperature of the North Atlantic (7).

The Bermuda cold area.—According to the Deutsche Seewarte charts, in crossing the Atlantic along the "belt of highs," a region of minimum surface temperature commonly is met, except during midsummer, in the general neighborhood of the Bermudas. What this low surface temperature is due to is not certain, but it seems to be connected with and dependent upon the strength and temperature of the Labrador current. If so—that is, if the surface temperature of the Bermuda cold area is lowest when the amount of "cold" brought by the Labrador current is greatest and least pronounced when this supply of cold is at a minimum—it clearly follows that the Bermuda "high" and, therefore, the temperature of the eastern United States must depend in part upon the Labrador current; that is, during the winter, the stronger this current the more intense the Bermuda "high," and the greater the excess of the average temperature of the eastern United States above its normal temperature. Hence, during the winter, a strong and persistent Labrador current would seem, through the creation and maintenance of a well-defined Bermuda "high," to give the eastern United States a marine climate and thereby to hold its average temperature well above its normal value. On the other hand, a relatively feeble winter Labrador current would presage the absence of Bermuda "highs," the prevalence of westerly or northwesterly winds, and, therefore, a continental climate and abnormally low temperatures over all the eastern United States.

Hence daily information in regard to the surface temperatures in the region of the Bermuda "high," in addition to the usual meteorological data for the same region, might be of decided help to the American forecaster. Hence, also, if the surface temperature near the Bermudas be controlled by the Labrador current, it is obvious that a proper study and gaging of this current—the measurement of its cross section, velocity, and temperature—if made at the right times and often enough repeated, might furnish information that occasionally would justify a tentative forecast of the type of coming winter weather in the eastern United States weeks or even months in advance.

These latter measurements, those pertaining to the Labrador current, clearly would be difficult, at present, perhaps, entirely impracticable, to make. This fact, however, does not forbid a discussion of their potential meteorological importance.

Of course, if the above is the actual chain of cause and effect, it clearly does not end with the Labrador current, but until this important point is cleared up it would be premature, however obvious the next link, to attempt to follow it further.

CONCLUSION.

The general facts and conclusions of this paper are:

1. Some winters in the eastern United States are unusually mild and others exceptionally cold.

2. During mild winters this part of the country temporarily has a marine climate, during cold ones a continental climate.

3. The type of winter climate, marine or continental, in this section is largely determined by the presence or absence of the Bermuda "high."

4. Persistence, during winter, of the Bermuda "high" gives to the eastern United States a marine and, therefore, for it, an unusually mild climate. Continued absence of this "high," during winter, allows a continental climate and, therefore, exceptionally low temperatures, to extend quite to the Atlantic coast.

5. The cause of the Bermuda "high" seems to be a cold-water surface, a minimum surface temperature, along the belt of highs.

6. This low surface temperature in the region of the Bermudas may depend upon the temperature and strength of the Labrador current.

7. A knowledge of the surface temperature in the region of the Bermuda "high" probably would be of value to the American forecaster.

8. If the Bermuda "high" is, as it seems to be, dependent upon the Labrador current, then proper gaging of this current should give some indication (during winter at least and probably other seasons as well) a fortnight or a month ahead of the type of coming weather in the eastern United States.

9. A persistent strong Labrador current would seem to indicate a subsequent (fortnight or longer) development of a more or less equally persistent Bermuda "high," and through it the prevalence during winter of relatively warm weather throughout the eastern United States. On the other hand a long continued, weak Labrador current would indicate subsequent absence of Bermuda "highs" and the prevalence over the eastern United States of unusually low temperatures.

REFERENCES.

(1) **Abbot & Fowle.** *In* Smithsonian miscellaneous collections, 1913, **60**, No. 29.

Humphreys, W. J. *In* Bulletin Mount Weather Observatory, Washington, 1913, **6**:1.

(2) **Hoffmeyer.** *In* Meteorol. Ztschr., 1878, **13**:337–347, Plates.

(3) **Teisserenc de Bort.** *In* Annales, Bur. cent. météorol. de France, 1881. IV. p. 17–66, 224 charts.

(4) **Fassig, O. L.** *In* Am. jour. sci., New Haven, 1899, (4) **7**:319–340.

Garriott, W. B. Long-range weather forecasts. Washington. 1904. (Weather bureau bull. **35**.) p. 60–62.

Garriott, W. B. *In* Monthly weather review, Washington, January 1906, **34**:22–23.

(5) **Danske meteorologiske institut & Deutsche Seewarte** (Hamburg). Tägliche synoptische Wetterkarten für den Nordatlantischen Ozean ... Copenhagen, etc. f°.

(6) **Humphreys, W. J.** *In* Bulletin, Mount Weather Observatory, Washington, 1911, **4**:1–12.

(7) **Germany. Seewarte.** Atlantischer Ozean, ein Atlas. Hamburg, 1902.

INTERNATIONAL SIMULTANEOUS OBSERVATIONS.

As early as 1871, in the development of the meteorological work of the United States Signal Service (now the Weather Bureau) it became evident that our storms on land were affected by so large a portion of the atmosphere that they could not be satisfactorily studied on the thrice-daily weather maps of the United States as then in use. The same difficulty holds good with regard to the weather map of the United States now in use. In June, 1871, at my request the official forecaster, Gen. Albert J. Myer, as chief of the bureau, sent to captains and owners of vessels circulars and forms requesting tri-daily simultaneous meteorological observations at sea, especially along our coasts. This marine work of the Signal Service grew steadily, even rapidly, until 1887, when all its official work

in marine meteorology was, by order of the Secretary of War, turned over to the care of the United States Navy.

The next step toward enlarging the sphere of meteorological work in the United States was the successful combination of the whole civilized world in the study of the atmosphere as a unit. Already in July, 1869, Prof. Abbe had offered an international exchange between his own observation system under the auspices of the Cincinnati Astronomical Observatory and Le Verrier's European system.[1] One of the important steps toward attaining this object was to secure its indorsement by the other meteorological services of the world; this was the object of Gen. Myer's trip to Europe and the Vienna Congress in September, 1873. He first secured individual cooperation between the various other services and the United States, which was rather readily accomplished since they were then all favorably disposed toward this country. Finally he brought the project before the International Meteorological Congress for its approval as related in the REVIEW for February, 1914, page 94.

These efforts led to the establishment of the "Bulletin of International Meteorological Observations taken simultaneously at 7:35 a. m. [later changed to 7:00 a. m.], Washington mean time." The published daily bulletins cover the period from January 1, 1875, to June 30, 1884, while the corresponding daily charts extend from January 1, 1875, to December 31, 1887. On June 30, 1884, the publication of the daily bulletin was discontinued, but the daily map, the monthly summary, and the annual review were continued until their final cessation with December 31, 1887. Beginning July 1, 1884, the size of the published daily international chart was enlarged to four times its former size, and about July, 1885, the published monthly charts, accompanying the Monthly Summary and Annual Review, were enlarged to the same size, i. e., to the size of the manuscript compilation.

The international data in these bulletins were carefully worked over into a homogeneous system by rules established before the publication of the first number for 1878, and expressed in both English and metric measures. The daily bulletins appeared regularly just about one year after the dates to which they pertained. The material thus presented was primarily intended as a basis for the study of the dynamics of the atmosphere, and not for climatological study as such. It is a mistake to treat them from the latter point of view; the charts present strictly simultaneous daily conditions over the whole Northern Hemisphere and are based on a larger number of simultaneous observations than those used for the Daily Weather Map of the Northern Hemisphere that began with January 1, 1914.

The Bulletin of International Meteorological Observations with its charts was widely distributed throughout the world; a copy was sent to each of the cooperating observers. The data it contains seem, nevertheless, to have been used by very few persons outside the Weather Bureau. N. A. H. Poincaré, then president of the Meteorological Society of France, used the charts to locate the daily positions of the centers of tropical high pressures; he showed that these move northward or southward according as the moon is north or south of the Equator, thereby establishing the existence of an appreciable fortnightly lunar tide which is, however, without an appreciable influence on our daily weather.

[1] Assoc. sci. de France, Bull. hebd., Aug. 15, 1869, 6:100.

John P. Finley,[2] then lieutenant, plotted from the daily charts the distribution of storm tracks throughout the Northern Hemisphere. An interesting, valuable summary of the distribution of pressure and storm tracks is given in the Annual Report of the Chief Signal Officer, United States Army, for 1891, Appendix 17, pages 747–777, and a similar summary compiled by the late Prof. E. B. Garriott is presented on a much larger scale with charts in Weather Bureau Bulletin A.[3]

It has been stated [4] that the Bulletin of International Simultaneous Observations represents the finest piece of international cooperation in precise scientific work that the world has ever seen, paralleled only by the Ephemerides Mannheimensis of 1780–1790, or by Sabine's work in terrestrial magnetism, or by the International Polar Expeditions of 1882–83. It is very regrettable that meteorologists have so far made practically no use of its daily, monthly, and annual maps and its extensive series of homogeneous, simultaneous observations. The large scale of the charts makes them particularly adapted to detailed studies, such as that outlined on page 672, by Prof. W. J. Humphreys.

The Weather Bureau Bulletin of International Simultaneous Observations had a valued supplement in the Tägliche synoptische Wetterkarte des Nordatlantischen Ozeans, issued jointly by the Deutsche Seewarte and the Danske Meteorologiske Institut beginning with 1884; but this expensive publication relates to the North Atlantic ocean only.—C. A.

DO CLOUDS YIELD SNOW EASIER THAN RAIN?

By DOUGLAS F. MANNING.

[Dated, Alexandria Bay, N. Y., Jan. 25, 1915.]

In the MONTHLY WEATHER REVIEW for February, 1914, there was published an article of mine under the above title. Perhaps the following brief description of a snowfall that occurred here on January 21, 1915, may be of interest to the readers. The day was almost calm, the temperature hovered around 10°F., and the slight air movement was from the north. The sky had a peculiar grey or milky appearance, the sun shone rather feebly and could be looked at with the naked eye, but there was no halo or corona present; one looking toward the horizon could see that this gauze-like veil of cloud had a tendency to form in rolls running from northeast to southwest, but so thin and shallow that when looking straight upward one could hardly believe that the sky was clouded. From about 9:30 a. m. until some time after 4 p. m., large feathery flakes of snow filled the air. The flakes were of the most exquisite formation; sometimes they ceased falling for a brief period only to start again. The snow fell to the depth of about 4 inches, but was of such a light, fine texture that it would hardly have been measurable as water. It is very certain that no precipitation could possibly have occurred from any such cloud in the summer season. This cloud sheet was of low altitude.

[2] See Sailors' Handbook of Storm Tracks, etc., by J. P. Finley. Boston, 1889.

[3] **Dunwoody, Henry Harrison Chase.** Summary of International Meteorological Observations. Washington, 1893. 10 leaves, 61 charts. 19 by 23½". (Weather Bureau Bull. A.)

[4] See report of the International Meteorological Congress held at Chicago, Ill., Aug. 21–24, 1893. Part II. Washington, D. C., 1895. p. 257. (Weather Bureau Bull. **11**, pt. 2.)

FOREIGN DISTRIBUTION OF THE MONTHLY WEATHER REVIEW DURING 1914 AND 1915.

[Dated Weather Bureau, Washington, D. C., Feb. 8, 1915.]

The interruption to commerce which arose at the beginning of August, 1914, caused the United States to suspend all foreign shipments of its publications through the International Exchange Service. For this reason foreign subscribers and recipients of the Monthly Weather Review will find their files interrupted after the issue for March, 1914, the last issue forwarded through the International Exchange Service.

During October, 1914, shipments of the Review were gradually resumed, including back numbers and up to the latest issue, except those to Austria-Hungary, Belgium, France, Germany, Russia, and the Balkin States, ncluding Serbia. Shipments have not yet been authorized to the countries mentioned, except those to France beginning sometime in January, 1915.

Complete sets of the delayed issues are reserved for those of our foreign recipients who are thus temporarily cut off, and these will be forwarded by the International Exchange Service to their destinations, as soon as an opportunity presents itself.

Beginning February 1, 1915, the Weather Bureau will forward for the time being its *current* publications *by mail* to all countries that can not yet be supplied through the International Exchange Service.

Foreign recipients are requested to notify the Chief of Bureau, United States Weather Bureau, Washington, D. C., of the nonreceipt of back numbers presumably forwarded to them. So far as possible such missing numbers will be replaced.

(Signed) C. F. MARVIN,
Chief of Bureau.

SECTION III.—FORECASTS.

STORMS AND WARNINGS FOR DECEMBER.

By EDWARD H. BOWIE, District Forecaster.

[Dated, Washington, Jan. 15, 1915.]

At the beginning of the month high-pressure areas were over the New England coast and the eastern Rocky Mountain region, while pressure was low over the Rio Grande Valley, western Ontario, and on the extreme North Pacific coast.

The northeastern high area passed eastward and gave gave place to lower pressure in connection with the western Ontario low area, while the high area over the eastern Rocky Mountain region moved northeastward to Quebec, where it persisted until the 7th.

The Rio Grande Valley storm moved slowly northeastward to southern Mississippi by the morning of the 3d and on the evening of that date there were two centers, one poorly defined over western Tennessee, where it persisted for several days, and the other over Alabama. The latter center moved slowly eastward, on the morning of the 7th being central east of Hatteras with increased intensity. By the following morning it had passed to the southern New England coast, and by the 9th was over the Banks of Newfoundland, having caused general precipitation over the Gulf States and territory east of the Mississippi River. On the 4th storm warnings were ordered for the Atlantic coast from Cape Henry to Cape Cod and repeated on the 5th and 6th for the area indicated and extended to Eastport. Warnings were again repeated on the 7th. This was one of the severest storms of record and caused phenomenally high-tides and high-winds and rains along the Middle Atlantic seaboard. Considerable property damage was done along the Delaware and New Jersey coasts.

An offshoot from a storm of moderate intensity that prevailed over the North Pacific coast from the 2d to 5th, was central over southwestern Utah on the morning of the 5th, and thence moved southeastward to the mouth of the Rio Grande during the next 48 hours. It passed thence eastward across the Gulf of Mexico and, recurving over Florida, passed north-northeastward between the Atlantic coast and Bermuda to a position near Newfoundland by the morning of the 11th. This storm passed northeastward in the trough of the preceding low. Precipitation attended this disturbance over the Mississippi Valley and thence eastward. This disturbance, in connection with the high-pressure that prevailed along the northern border necessitated warnings of high-winds on the 8th for Lakes Michigan, Superior, and Huron.

From the 5th to the 10th pressure was high over the northern border. The high-pressure area that prevailed at the beginning of this period was reinforced by several different high areas from Canada, the most important being that of the 8th from Alberta which moved southeastward to the northern Gulf States and thence eastward and northeastward to the Canadian Maritime Provinces. Freezing temperatures occurred over the East Gulf and south Atlantic States, with frost as far south as central Florida, warnings of which were successfully issued.

A low-pressure area on the north Pacific coast gave off an offshoot that was central over southern Utah on the 11th, whence it passed southeastward to the mouth of the Rio Grande and thence eastward and northeastward across the Gulf States and up the Atlantic coast with greatly increased intensity in the trough of a storm that passed east-southeastward from western Ontario on the 12th to Lake Huron on the evening of the 13th. The southern storm on the morning of the 13th was near Pensacola, and on the following morning over Maine, with pressure reading at Greenville 29.00 inches. It thence moved slowly northeastward, its influence continuing over the Canadian Maritime Provinces until the 16th. Precipitation occurred over much of the country with heavy rains in Atlantic coast districts and heavy snows in portions of the Appalachian Mountains, the upper Ohio Valley and lower Lake region and parts of New York and New England for which warnings were previously issued. Storm warnings were ordered for the Gulf and south Atlantic coast on the 12th, on the Atlantic coast on the 13th, and again on the New England coast on the 14th, and winds of gale force occurred as indicated.

This storm was followed by a high-pressure area that first appeared over Alberta on the night of the 11th. An offshoot from this high area moved slowly southward to Idaho. On the 14th this offshoot had two centers, one over the northern Plains States and the other over Oklahoma. On the following morning a single center was over western Tennessee, and during the 24 hours following moved east-northeastward to West Virginia where it remained stationary until the 17th, when it was reinforced by another high area that first appeared over Saskatchewan on the 14th. The combined high moved northeastward to a position south of Nova Scotia by the 19th. Cold weather was general throughout the country in connection with these high areas and the line of zero temperatures extended as far south as central Kansas and the mountain districts of Virginia, and freezing temperatures were reported throughout the Gulf and South Atlantic States, warnings being issued previous to their occurrence. Frost warnings were also issued in California and frosts occurred as indicated, but with little if any damage reported.

The next low appeared over northern Manitoba on the 17th, and passed thence eastward to the Canadian Maritime Provinces by the 20th. Quite general precipitation attended this disturbance over the eastern half of the country.

The high area following was an offshoot from a high that came from British Columbia during the 17th. An eastward extension of this high was over Nebraska on the 19th and thence passed rapidly eastward to a position south of Nova Scotia by the 21st.

On the 17th a disturbance was off the northern California coast and on the following morning an offshoot from it was over northern Arizona and southwestern Colorado, where it remained until the 20th, during which day an offshoot from it moved to northeastern Arkansas, and on the morning of the 21st was north of Lake Erie as a secondary to a storm central northeast of Lake Superior.

These two centers passed rapidly eastward, and on the 22d were over the Grand Banks, having caused rains in southern and snows in central and northern districts from the southern Rocky Mountain region and Plains States eastward. On the 21st warnings for high winds were disseminated to Atlantic coast ports from Sandy Hook northward, and high winds occurred as indicated therein.

Another disturbance followed from Alberta, passing rapidly across the northern border to the Gulf of St. Lawrence by the 23d.

Following these lows another high appeared over British Columbia on the 20th, and an extension from it passed southeastward to northern Texas by the 21st, and thence slowly eastward to Tennessee by the 23d. It moved thence northeastward to the middle Atlantic coast by the 24th, and during the next 12 hours passed off the coast. On the 20th cold wave warnings were issued for portions of the Plains States. On the 21st cold-wave warnings were ordered for the northern portion of the west Gulf States, and warnings of frosts and freezing temperatures for the middle and west Gulf States, and on the 22d cold-wave warnings were issued for the interior of New England and northern New York. The warnings of the 20th and 22d were followed by changes in conformity with the advices. Those issued on the 21st, for portions of the Gulf States, failed of verification on account of the weather becoming cloudy and precipitation occurring. Freezing temperature, however, occurred over the northern portions of the district referred to.

This high was followed by a low that on the 23d was over southern Alberta, whence it passed eastward to the Grand Banks by the 25th. Another low appeared on the extreme South Pacific coast on the 22d and during the next two days advanced to southern New Mexico. It thence moved rapidly eastward to the east Gulf States by the 25th and was then forced southeastward and southward with decreasing intensity until by the 27th there remained only slight indications of a cyclonic circulation off the east Florida coast. The suppression of this low was caused by a high pressure area that on the evening of the 23d was over eastern Saskatchewan. By the 25th it had moved to North Dakota with some of the lowest temperatures reported thus far this season. On the following morning it was over Illinois and another high area had appeared over western New York. The high with a single center was off the New England coast on the following morning, and pressure was high over the entire Atlantic seaboard, remaining so until the evening of the 28th. The low temperatures accompanying these high areas were felt quite generally throughout the country, the line of freezing temperatures extending southward nearly to the Gulf coast.

The next low to cross the country developed in the trough of a North Pacific storm and on the 27th was over Arizona, a center at the same time being also over Alberta. By the 29th the southern center was over northeastern Missouri with increased intensity, and by the evening of the 30th it was over the Canadian Maritime Provinces. General precipitation in the form of rain in southern and snow in northern districts occurred in connection with this disturbance from the Plains States eastward. On the 28th storm warnings were ordered for the Gulf and on the following day for the Atlantic coast, and a number of stations reported the occurrence of high winds.

It was followed by a high area that first appeared over Saskatchewan on the 29th. Another center, an offshoot from the Pacific Ocean high, being at the same time over southern Idaho. The Canadian high moved southeastward to the Missouri Valley by the 30th and to Kentucky by the last of the month, while the Idaho high moved very slowly southeastward to northwestern New Mexico. Warnings of freezing temperatures were issued for the interior of Texas on the 29th, and temperatures occurred as indicated. On the evening of the 28th and the morning of the 29th cold wave warnings were ordered for almost the entire country from the Plains States eastward to the Appalachian Mountains, and on the 30th warnings were issued for New England and New York. Decided changes to colder weather occurred as indicated in the advices.

At the close of the month a low-pressure area was over Manitoba and the pressure was below normal and falling on the North Pacific coast. High pressure obtained from the St. Lawrence Valley to the middle Gulf coast, and the pressure was also high from Idaho to New Mexico.

NORTHERN HEMISPHERE PRESSURE.

Alaska.—Pressure averaged much above normal for all of Alaska except in the vicinity of Nome, where it averaged below normal. The greatest excess was in the area comprising Valdez and Sitka. Lows occurred about the 1, 3, 5–6, 8, 11, 15–16, 17–18, 22, 27, and 29–31; and highs about the 3–4, 7, 9–10, 12–14, 16–17, 18–19, 24, and 28–29. The storm on the first day of the month caused a great deal of damage in the vicinity of Nome, the Bering Sea ice pack being forced high up on shore and the water driven farther inland than for several years. The trails were reported impassable.

Honolulu.—Pressure averaged decidedly below normal, being continuously below the seasonal average from the 4th to 23d. The principal lows occurred about the 7, 9–10, 11–12, 13–14, 17, 20, and 26. The principal highs occurred about the 1, 23, and 30–31.

Azores.—Pressure averaged slightly above normal. Lows occurred on the 6, 10, 13, 27, and 29–30; and highs on the 2–4, 16, 18, 20–21, 23–24, 28, and 30–31.

Reports from Iceland and Siberia are not available.

79709—15——3

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, DECEMBER, 1914.

By ALFRED J. HENRY, Professor of Meteorology in charge of River and Flood Division.

[Dated Washington, D. C., Jan. 25, 1915.]

Texas.—Heavy local rains in the watersheds of the Guadalupe, middle Colorado, lower Brazos, and lower Trinity on the 1st caused the Trinity at Dallas to overflow its banks on the 3d, the Guadalupe to reach the flood stage at Victoria on the 4th, and the Colorado to attain a bank-full stage on the 2d. These freshets subsided quickly.

The rains continued intermittently until the morning of the 3d, but they were light as a rule.

Carolinas, Georgia, and Tennessee.—The same storm caused quite general rains in the Carolinas, Georgia, and Tennessee on the 4th and 5th, ceasing on the last-named date. These rains caused the rapidly flowing streams of the foothills country in the Carolinas to reach and pass slightly above flood stages. A second short period of general rains occurred over Tennessee and the Carolinas on the 25th, and finally, on the 29th, another period of general, but not especially heavy, rains occurred. The rivers of South Carolina were in flood on the 26th and 27th and those of North Carolina about a day later, the details being shown in the table below. A portion of the Tennessee River in the Chattanooga district barely reached the flood stage on the 28th. There was no financial loss.

TABLE 1.—*Flood crest stages in Carolina rivers during December, 1914.*

River.	Station.	Flood stage.	Crest stage.	Date.
North Carolina.		*Feet.*	*Feet.*	
Roanoke	Weldon	30.0	33.0	Dec. 8
Neuse	Smithfield	13.0	17.8	Dec. 28
Cape Fear	Fayetteville	35.0	41.0	Dec. 27
Tar	Greenville	13.0	13.5	Jan. 1
South Carolina.				
Saluda	Pelzer	7.0	8.6	Dec. 5
Do	do	7.0	7.6	Dec. 26
Do	Chappels	14.0	14.0	Dec. 7
Do	do	14.0	14.0	Dec. 28
Broad	Blairs	14.0	15.9	Dec. 14
Do	do	14.0	16.9	Dec. 27
Congaree	Columbia	14.0	15.5	Dec. 3
Do	do	14.0	16.1	Dec. 27
Catawba	Catawba	11.0	17.0	Dec. 6
Do	do	11.0	15.2	Dec. 27
Wateree	Camden	24.0	29.5	Dec. 4
Do	do	24.0	30.5	Dec. 27
Great Peedee	Cheraw	27.0	29.4	Dec. 7
Do	do	27.0	33.2	Dec. 27

TABLE 2.—*Money loss due to floods in the Carolinas, December, 1914.*

Items.	North Carolina.	South Carolina.
Bridges, highways, etc.		$2,650.00
Crops		600.00
Live stock		1,790.00
Suspension of business	$5,000.00	555.00
Total money loss	5,000.00	5,595.00
Total lives lost		4
Estimated saving by warnings	10,000.00	35,400.00

Arizona.—A 3-days rainfall over southern Arizona on the 22d to 24th filled all streams and dry channels of that region to overflowing. The resulting damage, after making allowance for the usual exaggeration of newspaper reports, was undoubtedly heavy. The greatest destruction appears to have been done in the Santa Cruz River Valley, south of Tucson. That river, which terminates in the desert near Tucson, is said to have attained a width of more than a mile and a half in places south of Tucson. The mountainous nature of the basin of the upper Santa Cruz and the San Pedro Rivers added greatly to the suddenness of the flood both in rising and decaying. The flood in the Gila at Florence, the only gaging station on the river, continued over several days. The report from that station for the several dates during the continuation of the flood follows. The flood stage is 3 feet.

Date.	Hour.	Stage.	Above flood stage.	Remarks.
		Feet.	*Feet.*	
Dec. 18		4.0	1	
19	9:30 a. m.	4.0	1	
19	6:00 p. m.	6.0	3	
20	8:45 a. m.	8.0	5	
20	4:00 p. m.	10.0	7	
23	5:00 p. m.	9.6	6.3	
24	8:00 a. m.			Approach to bridge washed away. No reading.
25	9:00 a. m.	7.6	4.6	

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

SNOWFALL AT HIGH ALTITUDES, DECEMBER, 1914.

Arizona.—While the greater part of the precipitation for December occurred in the form of rain throughout the mountain districts of the southern half of the State, except in the most elevated regions, more than the average amount of snowfall was reported from most sections, owing to the unusually stormy conditions. Notwithstanding the rains and considerable melting, an average depth or more of snow with a high water content was generally reported from the mountain districts at the close of the month.

In the Salt River Watershed, reports from the White Mountain districts, the northern slopes of the Blue Range, and from the northern divide were more promising than usual, so early in the season, for an adequate spring run-off to the Roosevelt Reservoir. At the end of the month there were from 8 to 12 inches of snow at the higher elevations on the northerly slopes, with the snow line extending approximately to the 6,000-foot level.

In the southeastern counties the snowfall was heavy in the mountains, but there was much melting, leaving but an average amount in the Huachuca and the Chiri-

cahua Ranges at the close of the month. Less than the average was reported from the Pinal Mountains, while the amount at the higher levels of the Graham Mountains was unprecedented for December.

As usual, there was no snow of importance remaining in the Bradshaw Mountains, and only the average covering appeared on the higher peaks of the Verde Valley. In the Mogollon Mountains on the northerly slopes from 6 to 18 inches was reported, the snow line extending to the 6,000-foot level, with drifts and shaded patches as low as 5,000 feet.

To the northward, at the end of December, there was somewhat more than a foot of snow on Bill Williams Mountain, from 2 to 3 feet on the San Francisco Peaks, and more than the usual amount over the northern plateaus, above the 7,000-foot level.—*Robert R. Briggs, Section Director.*

California.—The snowfall during the month was slightly in excess of the average and was well distributed throughout the mountain regions of the State. The snow on the ground is generally well packed and contains a good amount of water. There is very little snow below the 3,000-foot level.—*George H. Willson, District Forecaster.*

Colorado.—December was not so dry as November, and there has been an increase in the amount of snow in the mountains, despite the large number of bright, sunny days. The average depth on the ground, however, is still small; in fact, the least for the end of December in five years on all watersheds except the Rio Grande and San Juan. While conditions on these two watersheds have been relatively more favorable than on the western and eastern watersheds, the amount of snow is less than usual.

The average water content of the snow on the ground at the end of December was as follows: South Platte, 0.40 inch; North Platte, 0.51 inch; Arkansas, 0.65 inch; Rio Grande, 1.10 inch; Grand, 0.63 inch; Gunnison, 1.26 inches; Yampa and White, 0.76 inch; and San Juan, 1.80 inches.—*F. H. Brandenburg, District Forecaster.*

Idaho.—Following an abnormally dry November, December was the driest month of the name since Statewide records were begun in 1892. The snowfall at mountain stations ranged from 3 to 20 inches. There were few extremely low temperatures, but the month was persistently cold, the mean temperature having been next to the lowest on record. The snow, having fallen during the prevalence of low temperature, was light, and possessed an unusually small water content. The snow was drifted very little, and the soil was frozen to an unusual depth. In all parts of the State except the Panhandle the snow supply at the close of the month was much below normal.—*Edward L. Wells, Section Director.*

Montana.—November and December, 1914, like the corresponding months of 1913, were deficient in precipitation, and there was a corresponding deficiency in the amount of snow accumulated in the high mountain regions. October was a wet month, and several feet of snow fell at high altitudes in the main range and most of the high ranges to the east of this. In the valleys and foothills the October precipitation was mostly rain, or moist snow, which soon melted, and the bulk of the moisture was taken up by the soil, while at elevations above 7,000 feet this early fall of snow has become very hard and icy as the result of warm days and freezing nights. The greater portion of the snow remaining in the mountains fell during the October storm.

The ground is generally bare below 6,000 feet elevation, and at no time have the ranges been covered to a sufficient depth to seriously interfere with the grazing of stock.—*R. Frank Young, Section Director.*

Nevada.—The depth of snow at the close of the month was generally less than on December 31, 1913. Prof. J. E. Church, jr., of the University of Nevada, reports that the snow on Mount Rose was about 10 inches deep at the 6,000-foot level, 20 inches at the 8,000-foot level, and 30 inches at the 9,000-foot level. The density of the snow was approximately 19 per cent. The average depth south of Mount Rose and north of Lake Tahoe, was about 24 inches.

Mr. A. L. Smith, the observer of the university at Tahoe, Cal., reports that the depth of snow on the ground December 30, 1914, was 13 inches, as against 26 inches on the corresponding date in 1913.

Lake Tahoe was at a stage of 7.13 feet, as against a stage of 4.60 feet at the close of December, 1913.—*Henry F. Alciatore, Section Director.*

Oregon.—The amount of snow in the Oregon mountains at the end of December was much less than usual. Weather was cold with east winds prevailing for more than half of the month. These winds are dry winds, and the little snow that fell has drifted considerably, but it is not well packed. So far a shortage of irrigation water is indicated, but this shortage could easily be overcome during the remainder of the season.—*Edward A. Beals, District Forecaster.*

New Mexico.—December was a cold, cloudy, stormy month, with heavy snowfall over practically the entire State, except the lowest southern valleys. The average fall for the State was 10.6 inches, not quite so great as December, 1913, but southern counties, especially southwestern, had heavy rains, bringing the average precipitation for the month far above December, 1913.

The accumulated depth at the close of the year averaged 10 to 12 inches over the highest parts of the main range at the headwaters of the Canadian. The headwaters of the Pecos were better favored, but even there the stored depth was small. A like condition prevailed over the Capitan, White, and Sacramento Mountains of the southeast, and the Black in the southwest. While over the headwaters of the Rio Grande, San Juan, and northwest a depth of 15 to 30 inches was reported. The soil of the State was well filled with moisture, and conditions thus far appear favorable.—*Charles E. Linney, Section Director.*

Utah.—Snow in the hills and mountains, and, in fact, in all the valleys of Utah, was lighter at the end of December, 1914, than for many years. The deepest snow reported was 18 inches near Manti, Sanpete County. Every correspondent reported snow below the average depth for this time last year, and that from the December indication the water supply will be below normal. The snow, as a rule, was neither drifted nor packed.—*Alfred H. Thiessen, Section Director.*

Wyoming.—The amount of snow in the mountains and in the forests of Wyoming at the close of November was inappreciable. At the end of December, while amounts had increased substantially, observers at all stations reported less than normal. Owing to the low temperature, little was wasted by melting and little by the wind, which was light. The most favorable conditions appear on the watersheds of the Green, North Platte, and Snake Rivers; the least favorable on those of the Tongue and Powder Rivers, where amounts are far below normal.

A depth of 22 inches is the greatest reported on the North Platte watershed, 24 inches on the Snake River,

and 25 inches on the Gallatin River watershed. Amounts in Yellowstone Park vary greatly on the different watersheds and as to exposure.

As might be expected, the water equivalent of the snow where deepest and well settled is greater than where the covering is light.—*R. Q. Grant, Section Director.*

MEAN LAKE LEVELS DURING DECEMBER, 1914.

By UNITED STATES LAKE SURVEY.

[Dated Detroit, Mich., Jan. 4, 1915.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during December, 1914:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.08	579.62	571.31	244.83
Above or below—				
Mean stage of November, 1914	−0.37	−0.30	−0.13	−0.42
Mean stage of December, 1913	−0.62	−0.72	−0.83	−1.08
Average stage for December, last 10 years	−0.23	−0.61	−0.45	−0.77
Highest recorded December stage	−1.05	−2.90	−2.22	−2.78
Lowest recorded December stage	+0.88	+0.62	+0.45	+1.40
Probable change during January, 1915	−0.3	−0.2	0.0	+0.1

FLOODS IN NEW ENGLAND RIVERS.

By ALFRED J. HENRY, Professor of Meteorology.

[Dated, Weather Bureau, Washington, D. C., January —, 1915.]

Floods in New England are due almost wholly to the breaking up of ice and the melting of snow on the headwater streams. When this annual event occurs in conjunction with heavy and prolonged rains the ordinary spring freshet becomes a damaging flood. The occurrence of heavy rains over New England is more or less fortuitous; hence the number of destructive floods is not great.

Thanks to the industry of Mr. W. W. Neifert, official in charge of the Hartford, Conn., Weather Bureau station, it is possible to present here a table of flood crests at Hartford extending back to the middle of the nineteenth century; also a statement of the maximum stages in the Connecticut at Springfield and Holyoke, Mass., extending back to 1870. The records of the earlier years, 1850–1870, are from the annual reports of the Chief of Engineers, etc., and the second source of information is the records of the Essex Company of Lawrence, Mass., as published in House Document No. 9, Sixty-second Congress, first session.

Only floods of considerable magnitude are included in this table. The present flood stage in the Connecticut at Hartford is taken as 16 feet above the zero of the local gage, and the highest stage ever recorded is 29.8 feet. It is therefore assumed that a 20-foot stage at Hartford corresponds to a serious flood there. A 20-foot stage in the Merrimac at Lawrence, Mass., causes inconvenience but no serious damage if the mills are warned of the approaching flood. These stages have been the criteria for selecting the floods listed in Table 1. If the gage height at either station was 20 feet or more it is considered and entered as a flood and the corresponding gage heights at the other stations are given, although they may not have been as much as 20 feet. This explains the appearance of stages less than 20 feet in the table at both Lawrence and Hartford. The times of the maximum stages at Holyoke and Springfield generally harmonize with those for Hartford. When this is not the case it is manifest that the flood recorded at the lower station was not general in the middle and upper reaches of the river.

TABLE 1.—*Chronological list of floods in New England, 1850–1913.*

Year.	Merrimac River.		Connecticut River.					
	Lawrence, Mass.		Hartford, Conn.		Springfield, Mass.		Holyoke, Mass.	
	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.
	Feet.		*Feet.*		*Feet.*		*Feet.*	
1850	22.7	May 1	20.0	May —			9.6	
1852	28.9	Apr. 23	23.2	Apr. 24				
1853			20.5	Nov. —				
1854	22.3	May 2	29.8	May 1	22.2			
1856	15.1	Aug. 23	23.3	Aug. 22				
1857	21.5	Apr. 16	19.5	Feb. 21				
1857	17.6	Oct. 28	18.2	Oct. 28				
1859	24.1	Mar. 21	26.4	Mar. 19				
1861	20.2	Apr. 16	21.5	Apr. 17				
1862	24.2	Apr. 21	28.7	Apr. 21	22.0	Apr. —		
1863	21.1	Apr. 20	22.2	Apr. 20				
1864	23.0	Mar. 8	17.2	Apr. 29				
1865	23.0	Mar. 18	24.8	Mar. 20				
1866	15.6	Feb. 15	20.5	Feb. 26				
1867	18.7	Apr. 19	17.2	Feb. 17				
1868	16.4	Mar. 20	21.5	Mar. 19				
1868	20.2	May 25	20.0	May 23				
1869	21.4	Apr. 23	26.7	Apr. 23				
1869	24.5	Oct. 6	26.3	Oct. 6	20.5	Oct. —		
1870	21.7	Jan. 4	19.2	Jan. 4				
1870	20.0	Feb. 21	21.3	Feb. 20				
1870	27.8	Apr. 21	25.3	Apr. 21				
1871	16.9	Mar. 14	16.5	Mar. 13				
1871	16.6	May 8	18.7	May 7	13.0	May 6		
1872	19.3	Apr. 12	21.0	Apr. 13	14.2	Apr. 12		
1873	18.8	...do....	21.2	...do....	15.0	...do....		
1874	20.8	Jan. 10	23.9	Jan. 9	17.5	Jan. 9	8.0	Jan. 9
1875	21.0	Apr. 6	18.4	Apr. 8	15.0	Apr. 5	6.0	Apr. 5
1876	20.6	Mar. 20	22.0	Apr. 16	17.0	Apr. 16	9.2	Apr. 16
1877	23.4	Mar. 29	22.9	Mar. 29	16.5	Mar. 29	8.8	Mar. 29
1878	21.0	May 1	18.5	Apr. 30				
1878	25.2	Dec. 12	24.5	Dec. 13	18.5	Dec. 11	9.2	Dec. 11
1879	17.8	May 2	21.5	May 1	15.8	May 1	8.5	May 1
1880	14.8	Apr. 6	15.4	Apr. 7	10.8	Apr. 6	5.7	Mar. 7
1881	15.4	Mar. 12	16.5	Apr. 26	11.5	Apr. 26	7.3	Dec. 31
1882	17.2	Mar. 4	14.8	May 31	10.9	Mar. 3	8.1	Sept. 24
1883	16.6	Apr. 14	20.5	pr. 15	14.6	Apr. 14	7.1	Apr. 15
1884	21.8	Mar. 29	21.6	Mar. 28	16.0	Mar. 28	7.2	Mar. 28
1884	20.1	Apr. 19						
1885	13.7	Apr. 6	18.0	Apr. 24	13.3	Apr. 24		
1885	13.8	Nov. 11	16.8	Nov. 8			6.9	Nov. 10
1886	21.7	Feb. 15	18.4	Jan. 7	16.0	Apr. 2	7.9	Apr. 2
1886			21.8	May 4				
1887	17.8	Jan. 31	22.5	Apr. 13	17.0	Apr. 13	8.2	Apr. 13
1888	19.5	May 1	19.4	Apr. 8	17.7	May 1	8.9	May 1
1888			21.8	May 4				
1889	14.4	Nov. 30	15.6	Nov. 30	11.3	Nov. 29	5.0	Nov. 29
1890	14.6	Apr. 17	15.2	May 9	11.7	Oct. 21	5.8	Sept. 18
1890	17.1	Oct. 21	16.0	Oct. 26				
1891	20.2	Mar. 25	17.5	Jan. 21	14.2	Apr. 17	6.7	Apr. 19
1892	15.5	May 24	18.3	June 16	13.7	June 16	6.5	June 15
1893	21.3	May 6	24.0	May 6	18.1	May 5	8.4	May 5
1894	14.8	Mar. 9	13.8	Apr. 25	10.4	Apr. 26	4.8	Apr. 25
1895	26.9	Apr. 16	25.7	Apr. 16	20.2	Apr. 17	9.6	Apr. 17
1896	29.7	Mar. 3	26.5	Mar. 3	20.2	Mar. 3	9.5	Mar. 2
1897	14.4	Apr. 10	17.0	Apr. 10	15.2	June 12	7.0	June 11
1897	20.4	July 16	20.8	July 16			7.4	Dec. 16
1897	18.8	Dec. 17						
1898	18.5	Mar. 15	20.0	Mar. 16	15.5	Mar. 15	7.1	Mar. 21
1899	19.3	Apr. 17	22.0	Apr. 27	16.1	Apr. 27	7.4	Apr. 26
1900	22.5	Feb. 15	23.4	Feb. 15	17.0	Feb. 14		
1900	18.7	Apr. 21	22.8	Apr. 22			10.2	Apr. 21
1901	26.4	Apr. 9	25.8	Apr. 10	19.07	Apr. 9	11.4	Apr. 8
1901	17.3	Apr. 26	22.7	Apr. 23				
1902	24.3	Mar. 4	25.5	Mar. 4	19.2	Mar. 4	10.8	Mar. 4
1902	17.7	Mar. 19	19.8	Mar. 18				
1903	20.5	Mar. 13						
1903	18.8	Mar. 25	23.4	Mar. 25	17.4	Mar. 25	10.6	Mar. 24
1904	21.5	Apr. 30	21.4	Apr. 30				
1904	17.7	Mar. 28	19.5	Mar. 28	15.3	Mar. 28	9.5	Mar. 27
1905	20.1	Mar. 30	24.0	Apr. 2	17.5	Mar. 31	10.6	Apr. 1
1906	18.3	Apr. 17	19.8	Apr. 17	15.1	Apr. 17	8.9	Apr. 17
1906	19.5	May 30	18.5	May 30				
1907	15.3	Apr. 1	16.0	Apr. 1				
1907	18.0	Nov. 8	20.3	Nov. 9	15.4	Nov. 8	9.0	Nov. 8
1908			18.2	Mar. 31	13.1	Mar. 30	7.6	Mar. 30
1908	14.8	Feb. 17	18.5	Feb. 18				
1909	19.3	Apr. 16	24.7	Apr. 17	18.5	Apr. 16	10.6	Apr. 16
1910	16.1	Mar. 3	20.0	Jan. 23	15.0	Jan. 23	7.5	Mar. 27
1910			18.6	Mar. 3				
1911			15.5	Apr. 17	11.9	Apr. 7	7.2	Apr. 16
1911			16.0	Oct. 20				
1912	16.4	Apr. 9	21.2	Apr. 10	16.1	Apr. 9	9.3	Apr. 9
1913	19.6	Mar. 28	26.3	Mar. 29	20.9	Mar. 29	12.0	Mar. 28

GREAT FLOODS IN NEW ENGLAND RIVERS.

The great floods in New England during the last 63 years were those of April, 1852, May, 1854, April, 1862, October, 1869, April, 1895, and March, 1896.

We may distinguish two kinds of floods: (1) Those due to the occurrence of heavy and continuous precipitation in the warm season; and (2) those due to the occurrence of heavy rain in conjunction with a thaw in the winter or spring. The floods of 1854 and 1869 are typical of the first class; those of 1862, 1895, and 1896 of the second class.

The flood of 1869 was due to what was probably an unprecedented rainfall throughout New England and the adjoining territory on the west and southwest. Although the United States Weather Bureau was not in existence at that time, there was a small body of observers reporting to the Smithsonian Institution, of Washington, D. C., and from their reports we are able to compile a fairly accurate table showing the amount and horizontal distribution of the rainfall that produced the flood in question. This table appears in a subsequent portion of this paper.

The tendency to a maximum of flood frequency in the spring is a marked characteristic of New England Rivers. The distribution of floods by months is shown in the table below.

TABLE 2.—*Distribution of floods by months.*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Hartford, Conn.	2	3	10	20	7	0	1	1	0	1	2	1	48
Lawrence, Mass.	2	3	10	12	5	0	1	0	0	1	0	1	35

Floods due to rain.

We will first consider the summer floods or those floods due wholly to rainfall as distinguished from floods due partly to rainfall and in part to melting snow.

The flood of July, 1897.—The month of July, 1897, was remarkably rainy in New England. The floods of July 16, 1897, were confined mostly to the streams that drain into the Connecticut, the maximum stage of the Connecticut at Hartford was 20.8 feet, or 4.8 feet above its flood stage. It was due wholly to heavy and continuous rains in connection with a barometric depression that approached New England on July 12, extending southward from the St. Lawrence Valley to Georgia. On July 13 and 14 the eastward progress of the storm was retarded and heavy showers fell over New England. On the 13th the greatest amounts were recorded in Connecticut, viz:

	Inches.
Bridgeport, Conn	8.11
Canton	5.18
Middletown	5.09
New Haven	5.91
Southington	6.60
Windsor	6.90
Waterbury	6.03

The rains continued over the whole of New England on the 14th, being heavy in many places, but on the 15th, while there were showers at a number of places, heavy precipitation had ceased.

Fortunately, the rains in the upper watershed of the Connecticut did not exceed 5 inches in 24 hours at any single point. The flood in the Connecticut was, therefore, greatest in the lower part of the river.

The flood of October, 1869.—Probably the greatest of all "rain floods" in New England was the so-called "pumpkin flood" of October 6, 1869. This flood was remarkable in that it came at a time of year when the streams were at a very low stage. In point of magnitude the flood of 1869 at Hartford ranks as the sixth in the last 63 years. (See Table 1.) Since it was due to a rainstorm of wide extent and long duration we have compiled [1] the contemporaneous records of rainfall made by observers of the Smithsonian Institution, and present them in Table 3 below. The rainfall reports are arranged by States, beginning with Virginia and the District of Columbia.

TABLE 3.—*Precipitation in the storm of October 2–5, 1869.*

[In inches and hundredths.]

Location.		October, 1869.				Total for storm.	Remarks.
Station.	County.	2	3	4	5		
Virginia.		*In.*	*In.*	*In.*	*In.*	*In.*	
Comarn	King George	0.34	5.05	0.02	.....	5.41	5.05" in 18 hours.
Mulberry Hill	Isle of Wight	.....	3.16	.....	.....	3.16	3.16" in 15 hours.
Johnsontown	Northampton	0.10	.....	1.05	.....	1.15	
Hampton	Elizabeth City	0.30	.....	1.90	.....	2.20	1.90" in 24 hours.
Lexington	Rockbridge	.....	2.75	.....	.....	2.75	
Norfolk	Norfolk	0.35	1.20	.....	.....	1.55	
Snowville	Pulaski	.....	1.25	.....	.....	1.25	
Staunton	Augusta	.....	1.50	0.75	.....	2.25	
Vienna	Fairfax	.....	.....	4.50	.....	4.50	More than 24 hrs.
District of Columbia.							
Washington	Dist. Columbia	.....	.....	6.55	.....	6.55	All in about 24 hrs.
Maryland.							
Annapolis	Anne Arundel	0.13	3.42	1.83	.....	5.38	
Mount St. Marys	Frederick	.....	.....	5.14	.....	5.14	In 36 hours.
St. Marys	St. Marys	.....	.....	2.25	.....	2.25	
Woodlawn	Cecil	0.03	.....	3.94	.....	3.97	3.94" in 24 hours.
New Jersey.							
Greenwich	Cumberland	.....	.....	3.25	.....	3.25	
Vineland	do	.....	.....	2.87	.....	2.87	In 30 hours.
Moorestown	Burlington	.....	.....	2.41	.....	2.41	
Rio Grande	Cape May	.....	.....	3.50	.....	3.50	In 37 hours.
Trenton	Mercer	.....	.....	2.61	.....	2.61	In 33 hours.
New Brunswick	Middlesex	.....	.....	3.27	.....	3.27	
New Germantown	Hunterdon	.....	.....	4.43	.....	4.43	In 27 hours.
Paterson	Passaic	.....	1.09	3.06	.....	4.15	
Newton	Sussex	.....	.....	7.11	.....	7.11	5.21" in 27 hours.
Haddonfield	Camden	.....	.....	3.32	.....	3.32	In 28 hours.
Newark	Essex	.....	.....	3.30	.....	3.30	In 12 hours.
Pennsylvania.							
Canonsburg	Washington	1.00	.....	0.40	.....	1.40	
Franklin	Venango	0.14	0.15	0.13	.....	0.42	
Pennsville	Clearfield	.....	.....	0.57	.....	0.57	
Johnstown	Cambria	.....	0.76	.....	.....	0.76	
Carlisle	Cumberland	0.30	.....	4.20	.....	4.50	4.20" in 24 hours.
Fountaindale	Adams	.....	.....	4.58	.....	4.58	In 36 hours.
Lewisburg	Union	T.	.....	3.60	.....	3.60	
North Abington	Luzerne	.....	1.60	2.80	.....	4.40	In 30 hours.
Blooming Grove	Pike	.....	.....	7.50	.....	7.50	In 32 hours.
Dyberry	Wayne	.....	1.15	3.00	.....	4.15	All in 24 hours.
Hamlinton	do	.....	6.00	.....	.....	6.00	In about 39 hours.
Fallsington	Bucks	.....	.....	2.90	.....	2.90	In 27 hours.
Moorland	Montgomery	.....	4.50	.....	.....	4.50	
Plymouth Meeting	do	.....	.....	6.00	.....	6.00	In 27 hours; 4.10" in 12 hours.
Ephrata	Lancaster	.....	.....	8.05	.....	8.05	In 60 hours.
Mount Joy	do	.....	.....	8.00	.....	8.00	
Philadelphia	do	.....	.....	3.95	.....	3.95	In 31 hours.
Pocopson	Chester	0.04	5.00	0.20	.....	5.24	
West Chester	do	.....	.....	5.80	.....	5.80	In 36 hours.
Reading	Berks	.....	.....	6.73	.....	6.73	Do.
Tioga	Tioga	.....	1.50	0.50	.....	2.00	
New York.							
Little Genesee	Allegany	1.05	.....	.....	.....	1.05	
Governeur	St. Lawrence	.....	.....	2.87	.....	2.87	
N. Hammond	do	.....	1.07	1.40	.....	2.47	

[1] *See also* Francis, James B. Distribution of rainfall during the great October storm of 1869. Trans., Amer. soc. civil eng., New York, 1878, 7: 224.

TABLE 3.—*Precipitation in the storm of October 2–5, 1869*—Continued.

Location.		October, 1869.				Total for storm.	Remarks.
Station.	County.	2	3	4	5		
New York—Continued.		*In.*	*In.*	*In.*	*In.*	*In.*	
Cooperstown	Oswego		1.10	2.00		3.10	
Ardenia	Putnam			4.66		4.66	
Brookhaven	Suffolk			5.34		5.34	In 28 hours.
Erasmus Hall	Kings			3.46		3.46	
Hudson	Columbia			7.90		7.90	In about 34 hours.
Minaville	Montgomery			5.25		5.25	In about 36 hours.
New York City	Kings			4.00		4.00	In about 43 hours.
Do	do			3.98		3.98	
South Hartford	Washington		0.65	4.15	1.10	4.80	In 38 hours.
West Point	Orange			5.00*		5.00	In 36 hours.
Connecticut.							
Colebrook	Litchfield			8.44		8.44	In about 42 hours.
Canton	Hartford			12.35		12.35	
Brookfield	Fairfield			5.50		5.50	In 36 hours.
Hartford	Hartford			8.43		8.43	
Middletown	Middlesex			8.96		8.96	In 36 hours.
New Haven	New Haven			4.30		4.30	
Massachusetts.							
Amherst	Hampshire			5.84*		5.84	In 15 hours.
Hinsdale	Berkshire		1.80	3.50		5.30	3.10″ in 4 hrs; 4.70″ in 23 hrs.
Kingston	Plymouth			1.75		1.75	
Lawrence	Essex			3.56		3.56	In about 36 hours.
Lunenburg	Worcester			7.50		7.50	In about 35 hours.
Mendon	do			2.80		2.80	
Milton	Norfolk			1.15		1.15	In 19 hours.
New Bedford	Bristol			4.37		4.37	In 19½ hours.
Topsfield	Essex			1.77		1.77	In 28 hours.
West Newton	Middlesex			2.33		2.33	Do.
Williamstown	Berkshire			6.00		6.00	In about 39 hours.
Worcester	Worcester			4.75*		4.75	In 29 hours.
Cambridge	Suffolk			1.58		1.58	
Boston	do			1.76		1.76	
Georgetown	Essex			2.25		2.25	
Waltham	Middlesex			1.65		1.65	
Lake Cochituate	do			4.00		4.00	
Lowell	do			2.84		2.84	
Fitchburg	Worcester			7.53		7.53	3.99″ in 2½ hours.
Chicopee	Hampden			8.71		8.71	
Springfield	do			8.05		8.05	8.05″ in 37 hours.
Pittsfield	Berkshire			6.00		6.00	
Richmond	do			3.97		3.97	More than half in 3 hours.
Vermont.							
Middlebury	Addison			3.40	0.58	3.98	3.40″ in 30 hours.
Ferrisburg	do			3.50	0.87	4.37	
Brandon	Rutland			4.25		4.25	
Burlington	Chittenden			3.71		3.71	
West Charlotte	do		0.87	3.12	0.87	4.86	4.00″ in 20 hours.
Castleton	Rutland			4.60	1.97	6.57	4.60″ in 30 hours.
Craftsburg	Orleans			4.49		4.49	In 50 hours.
Lunenburg	Essex			3.90	0.10	4.00	3.90″ in 35 hours.
Randolph	Orange			5.00	0.30	5.30	5.00″ in 36 hours.
Woodstock	Windsor		1.75	4.60		6.35	6.35″ in 35 hours.
New Hampshire.							
Hanover	Grafton			5.88		5.88	
N. Barnstead	Belknap			7.40		7.40	In about 36 hours.
Weirs Landing	do			6.40		6.40	
Whitefield	Coos		1.50	3.41	0.40	5.31	2.75″ in 14 hours.
Stratford	do		1.17	2.53		3.70	
Tamworth	Carrol			6.35		6.35	In 30 hours.
Goffstown	Hillsboro		0.78	7.28		8.06	4.27″ in 3 hours.
Concord	Merrimack			7.40		7.40	4.00″ in 2 hours.
Dover	Strafford			3.20		3.20	
Maine.							
Standish	Cumberland			4.31		4.31	
Fort Preble	do			1.99		1.99	In 37 hours.
Cornish	York		2.63	3.80		6.43	2.63″ in 26 hours.
Gardiner	Kennebec			3.37		3.37	In 31 hours.
West Waterville	do			4.10		4.10	In 36 hours.
Rumford	Oxford			8.00		8.00	
Norway	do			6.70		6.70	2.50″ in 2 hours.
Oxford	do			6.70		6.70	In 36 hours.
Orono	Penobscot			2.13		2.13	
Houlton	Aroostook			3.60		3.60	In about 54 hours.
Lisbon	Androscoggin			2.70		2.70	
Williamsburg	Piscataquis		1.80	3.50		5.30	

* Gage overflowed.

From Table 3 we see that the rainstorm of October 2–5, 1869, was of wide extent and that its maximum intensity was of unusual duration. It is very exceptional that heavy rains persist for so long a period as 24 hours. The rains in the Ohio Valley during the latter part of March, 1913, are prominent examples of the kind of rains which fell over the lower portions of the Connecticut Valley during October, 1869. It will be noted that the Connecticut River had relatively higher stages along its lower reaches than in the upper portion of its course, due to the fact that the very heavy rainfall was apparently concentrated over the western portions of Massachusetts and Connecticut.

The lesson to be drawn from the foregoing appears to be that although summer floods, or more strictly speaking what may be called "rain floods," occur very infrequently in New England, the probability of such a flood can not be disregarded. The occurrence of flood-producing rains in the warm season, such as those of October, 1869, and July, 1897, seems to be due to an extraordinary combination of atmospheric conditions, such as may occur probably but once in a lifetime.

Spring floods due to rain and snow.

A destructive spring freshet or flood due solely to the breaking up of ice in the streams and the melting of the snow cover, is practically unknown. The accumulated snow on the headwaters of a watershed is therefore considered merely as an important modifying factor in flood causation. Further, the writer is of the opinion that, as a rule, the snow cover is of less importance in producing severe floods than is generally believed. Snow that has remained on the ground for some time melts almost imperceptibly into itself and thus the first effects of melting are to increase the density of the snow. Generally a subsequent freezing takes place, and the snow cover is finally not in a condition to melt rapidly, thus the danger of a severe flood due only to melting of snow becomes a remote probability.

New England flood of April, 1895.—The floods of April, 1895, and March, 1896, in New England streams were due in both cases to heavy and continued rains at a time when the snow cover was sufficient, if melted, to greatly intensify the flood waters.

The barometric minimum that was the direct cause of the rains that fell over New England on April 13, 14, 15, 1895, was not unusual in any way, but its movement across New England occupied about three days. On the 14th the center of the Low was partly over the ocean and partly over the land, a position favorable to a continuous inflow of air from the ocean. The precipitation of the second day was the heaviest of the storm period; at a number of places the amount exceeded 2 inches. On the third day the rains became lighter and ceased in some portions. The average precipitation for the storm is shown by States in Table 4.

TABLE 4.—*Average precipitation over New England, Apr. 13–15, 1895, by States.*

State.	Number of stations.	Average precipitation.
		Inches.
Maine	12	2.17
New Hampshire	16	2.87
Vermont	14	2.42
Massachusetts	35	2.01
Rhode Island	5	3.46
Connecticut	14	0.94

The central area of New England had, therefore, an average rainfall of slightly over 2 inches in the three

days. The extremes were of course much greater. At North Conway, N. H., the fall was 6.25 inches from the morning of the 13th until the morning of the 15th. Over 4 inches fell in 24 hours at North Bridgeton, Me., Plymouth and Berlin, N. H., Woodstock, Vt., and Natick, Mass.

Earlier in the month there had been considerable rain and the soil where not frozen was doubtless saturated with water; moreover there was still some snow on the ground in the central and northern portions of New Hampshire, Vermont, and Maine. The greater portion of this snow was melted and ran into the streams in connection with the heavy local rains of the 8th–10th of the month. The heavy rains of the 13th–15th, therefore, must have come upon streams already at a moderately high stage.

At the time of the flood no systematic measurements of the stages of the rivers of New England were being made by the Weather Bureau, and, so far as known, but few private measurements were made. The few actual records we have been able to obtain are as follows:

Stations.	Stages.	Below highest previous stage.
Connecticut River.	*Feet.*	*Feet.*
Holyoke, Mass.	9.3	2.7
Springfield, Mass.	20.3	1.9
Hartford, Conn.	25.7	3.4
Merrimac River.		
Lawrence, Mass.	26.9	2.8

New England flood of March, 1896.—A second severe flood occurred in New England rivers in March, 1896. In the Merrimac River this flood gave a stage of 29.7 feet at Lawrence, the highest stage recorded in the sixty-odd years during which measurements have been made.

The weather leading up to the flood was stormy and rainy. The rains began on February 29, 1896, and were universal over New England, the daily amounts varying from less than ½ inch up to as much as 4 inches. The average daily amounts for each of the New England States are shown in Table 5.

TABLE 5.—*Average precipitation over New England, Feb. 29 to Mar. 4, 1896.*

States.	Number of stations.	Average precipitation.					
		Feb. 29.	March.				Total.
			1	2	3[1]	4[1]	
Maine	11	1.00	1.94	0.25	0.57	0.25	4.01
New Hampshire	16	1.05	1.30	.73	.25	.14	3.47
Vermont	13	1.20	0.29	.16	.29	.07	2.01
Massachusetts	30	0.97	.74	.46	.40	.07	2.64
Rhode Island	6	1.22	.67	.21	.35	.06	2.51
Connecticut	13	2.62	.27	.11	.05	.02	3.07

[1] Precipitation on Mar. 3 and 4 was mostly in form of snow.

When the rain began there were from 1 to 2 feet of snow on the ground in the northern portion of New England, and except in the densest woods most of it melted and ran into the streams.

The storm which was the immediate cause of the rain advanced rapidly from the mouth of the Mississippi River on February 29, 1896. Its northeastward course over New England was, however, apparently blocked by high pressure over the Canadian maritime Provinces, and an area of high pressure advancing from the west across the Great Lakes. In any event, the ordinary movement of the storm to the northeast across New England was prevented, with the result that it lingered over southern New England until March 5, when it apparently moved eastward south of Nova Scotia.

The rain turned to snow on March 2, and the weather became much colder on the 3d and 4th, thus mitigating the severity of the floods.

New England flood of May 1, 1854.—There remains but one more great flood in New England to consider, viz, the flood of May 1, 1854. This flood gave the highest water in the Connecticut ever recorded at Hartford, Conn., and Springfield, Mass. It was not a remarkable flood in the Merrimac, the only other New England river for which reliable records are available. Although more than half a century has elapsed since the occurrence of the flood, the meteorological reports made at the time to the Smithsonian Institution show that the extremely high water in the lower Connecticut resulted from the prevalence of heavy rains, which began on the evening of Thursday, April 27, and continued practically without intermission until noon of Sunday, May 1, a period of about 90 hours. During these 90 hours the following amounts of rainfall were recorded:

	Inches.
Springfield, Mass.	5.16
Southwick, Mass.	7.52
Saybrook, Conn.	6.00
Pomfret, Conn.	3.45
Concord, N. H.	3.50
Manchester, N. H.	3.25
St. Johnsbury, Vt.	2.60
New York City.	4.67
Philadelphia, Pa.	4.87

and smaller amounts were recorded at many other places.

The 24-hour fall in this storm was not exceptionally large, the greatest recorded amount being 3.50 inches in 12 hours, at Southwick, Mass. It seems probable that in this storm the rains of greatest intensity fell over extreme southeastern New York, western Massachusetts, and western Connecticut. The precipitation for a part of the storm in Vermont, New York, and New Hampshire was in the form of snow. There may have been some snow on the north slopes of the watershed in New Hampshire and Vermont at the beginning of the warm spell that immediately preceded the storm, but of this we have no reliable record. The storm was preceded by warm southerly winds and thunderstorms over southern New England, New Jersey, and southeastern New York on April 25, 26, and 27. On the 27th there was a marked change to lower temperature over western Massachusetts, and a cold easterly rain immediately set in, continuing, as above stated, with but little intermission until Sunday, May 1.

PRECIPITATION AND RUN-OFF DURING A TYPICAL FLOOD.

Since it seems of interest to compare the precipitation and the run-off that occur during a typical New England flood, the writer has compiled the data for the flood of April 14–19, 1895, in the Merrimac River, New Hampshire.

The drainage basin of the Merrimac above Lawrence, Mass., embraces 4,664 square miles. The average precipitation over New Hampshire for the period April 13–15, 1895, was 2.87 inches, as averaged from the reports of 22 stations. Since 1 inch of rainfall over an area of 1 square mile involves 2,323,200 cubic feet of water,

then the above rainfall of 2.87 inches depth amounted to 6,667,584 cubic feet per square mile. Therefore the volume of water precipitated upon the 4,664 square miles of the drainage basin of the Merrimac during the period April 13–15, 1895, amounted in all to 31,097,611,776 cubic feet. This precipitation was carried off by the Merrimac as shown by Table 6.

TABLE 6.—*Discharge of the Merrimac River at Lawrence, Mass., Apr. 14–19, 1895.*

Date.	Stage.	Equivalent discharge per second.	Total daily discharge.
1895.	*Feet.*	*Sec.-feet.*	*Cubic feet.*
Apr. 14	*18.0	*34,300	*2,963,520,000
Apr. 15	19.9	40,267	3,479,068,800
Apr. 16	26.9	62,100	5,365,440,000
Apr. 17	24.2	54,800	4,734,720,000
Apr. 18	18.2	35,000	3,024,000,000
Apr. 19	15.2	26,000	2,246,400,000
Total			21,813,148,800

*Estimated; no reading made.

If no rain had fallen after the 13th it is estimated that the stage of the river due to the water supply then on hand would have been 10.5 feet, and that the total discharge for the 6 days would have equaled 6,531,840,000 cubic feet. Subtracting this amount from the actual total flood discharge, there remains 15,281,308,800 cubic feet, the approximate discharge due to the rains. The total precipitation that caused the flood was 31,097,611,776 cubic feet and the percentage of run-off is therefore 49. This run-off value corresponds fairly well with the run-off values for certain Maine rivers given in Table 7.

TABLE 7.—*Rainfall and run-off for certain drainage basins in Maine for 1903.*

Basin and river.	Gaging station.	Drainage area.	Precipitation.*	Run-off.*	
Penobscot:		*Sq. miles.*	*Inches.*	*Inches.*	*Per cent.*
Mattawamkeag	Mattawamkeag	1,510	36.3	19.40	53
Piscataquis	Foxcroft (near)	280	36.5	25.33	69
Penobscot, East Branch.	Grindstone	1,130	35.0	16.44	47
Kennebec:					
Kennebec	The Forks	1,670	31.7	21.30	67
Do	North Anson	2,880	32.0	19.20	60

* Precipitation from the few existing stations of the Weather Bureau; run-off from the values published in the Water Supply Papers of the U. S. Geological Survey.

SECTION V.—SEISMOLOGY.

RESUMPTION OF SEISMOLOGICAL WORK.

By C. F. MARVIN, Chief of Bureau.

[Dated, Weather Bureau, Washington, D. C., July 1, 1914.]

Authority having been granted by Congress for the Weather Bureau to conduct seismological work, to begin with July 1, 1914, this work will accordingly be resumed.

As but limited funds are available for inaugurating the work, it will consist at the beginning of a systematic collection of noninstrumental reports, to be rendered on postcards or other appropriate form, giving the essential features of such slight earthquakes as are likely to be felt in almost any part of the United States. Particular attention will be paid, however, to the Pacific coast and Rocky Mountain regions; the Mississippi Valley in the vicinity of Missouri; certain parts of New York State and New England, and possibly the region in the vicinity of Charleston, S. C.

It is believed that by the collection and study of numerous reports of this character it will be possible to locate sections of the United States where seismic motion on existing fault lines is taking place with some frequency and regularity. The location and mapping of these points of weakness are of great importance in the conduct of certain kinds of engineering work, especially those relating to great water-supply projects or similar engineering undertakings where it is necessary to provide against injuries resulting from possible earthquake motions.

The development of the work along instrumental lines, which will proceed as rapidly as funds permit, contemplates the establishment of a limited number of instrumentally-equipped stations that will serve to yield record not only of sensible seismic phenomena, but also of the great unfelt vibrations resulting from large distant earthquakes.

The seismological work will be under the supervision of Professor William J. Humphreys.

SEISMOLOGY.

By W. J. HUMPHREYS, Professor of Meteorological Physics, in charge of Seismological Investigations.

[Dated, Weather Bureau, Washington, Feb. 1, 1915.]

HISTORICAL AND INSTRUMENTAL.

Although earthquakes have so appealed to the imagination as to command a prominent place in mythology, in tradition, and on the pages of all authentic history, nevertheless the science of such phenomena instead of being old like astronomy and geometry is one of the youngest. Noninstrumental records of earthquakes have it is true, been kept in Japan and Italy for many centuries, and even ingenious devices that would indicate the occurrence of disturbances were set up in China nearly 1,800 years ago, yet modern seismology, the science of earthquakes and the interpretation of their many phenomena, is indeed so very modern as to require considerable liberality in conceding it an age of even 30 to 40 years. It began only with the use of apparatus so designed and constructed as to record the times of beginning and ending of every material tremor, even though not sensible to man, its amplitude, direction, period, and other characteristics. As these instruments have increased in number and distribution throughout the world our knowledge of the structure of the earth, both in the outer shell and in its deeper portions, has become more abundant and more specific.

The designing of apparatus that will record the onset, the period, the amplitude, and the subsidence of a vibration, often feeble beyond human sense to detect, caused by a break or a slip in the rocky crust of the earth thousands of miles away, in the very antipodes, it may be, challenges, as one may well imagine, the highest type of inventive genius, while its construction and maintenance puts to test the skill of the trained mechanician. Similarly, the interpretation of these records calls for much thought by the geophysicist and the extensive use of none too easy mathematics.

From this it might seem that seismology is an ideal subject for the private diversion of the abstract scientist, as indeed it is. Those who attempt difficult problems for the mere exhilaration they afford, or revel in the luxury of intricate equations, can find in seismology every excuse for endless self-indulgence.

APPLIED OR PRACTICAL.

"To have is to use" is an axiom that applies as well to knowledge as it does to land and chattels. Steam soon moved many things besides teakettle lids. Similarly, the knowledge, so far as that has already been gained, of where earthquakes occur, why they occur, and how the earth vibrates under their shocks, has already found eminently practical applications, and it is quite certain, from the nature of these applications, that they will keep in close touch with the growing knowledge. Thus the fact, now generally recognized, that perhaps all notable earthquakes are due to sudden breaks and displacements in the rocky crust, leads to two important deductions: (*a*) That each geologic fault, each surface across which the strata are nonconformable or displaced, presumably has been the origin, the focus, or epicenter of from one to many earthquakes; (*b*) that since, in general, a break remains forever a weak place in the earth's crust, earthquakes are most likely to recur just where they occurred before. The first of these deductions, because it concerns things that have already passed, some of them hundreds, thousands, possibly millions of years ago, can neither command the attention of the engineer nor catch the interest of the man of affairs. The second deduction, however, concerns not the past but the future and therefore has a practical value that increases directly with the frequency with which disturbances recur. Hence wherever seismic shocks are at all frequent, especially in populated portions of the world, a careful engineer would not span an active geologic fault with a bridge, aqueduct, dam, or other important structure if it could be avoided. Neither would a properly informed and prudent banker finance such an enterprise unless the success of the project could be safeguarded.

Indeed it would be well to keep these considerations clearly in mind whenever building important permanent structures even in the least disturbed regions, for it can not be said with certainty that there is any place entirely free from the earthquake's shock nor can anyone foretell when it will come or how severe it may be.

Where such disturbances are rare it often is not advisable to incur heavy expense simply to minimize the danger. But the more important the structure in question, the more vitally it affects the community; the more frequent and severe the shocks, the greater the need for precaution—the avoidance of all well-marked seismic breaks or geologic faults.

But precautions, however urgent, can not in general be taken unless the engineer is first provided with the necessary information—with detailed maps locating seismic centers. As this need applies equally to all parts of the country, it clearly is a proper function of the National Government to supply, as rapidly as practicable, maps and other information on seismic frequency and seismic severity. But how shall the Government fulfill this function? Through what agency shall it operate in constructing these maps which are so essential?

In answer to these questions it may be said that many have long recognized that of the various Federal scientific institutions the Weather Bureau is the best fitted to undertake this work, because it already has approximately 200 principal stations, widely distributed over the entire United States and manned by trained observers familiar with the maintenance of delicate automatic instruments. In addition it receives reports from over 4,000 cooperative observers. Thus it has all the necessary organization for the continuous and systematic collection of data concerning earthquake phenomena, and Congress has recently authorized it to do this work.

For the purpose of furthering this work as much as possible the bureau will assemble and publish as often as may be necessary not only its own instrumental records, but also any of reliable nature that may kindly be offered for that purpose by other institutions operating seismographs. In addition to this it is collecting and will publish noninstrumental reports of earthquakes. Question cards on which these reports may easily be rendered have already been sent to many persons throughout all the States and will be furnished to any others who are sufficiently interested to cooperate without cost to the bureau in this important work. The time required of each observer to prepare these card reports can not amount, on the average, to more than a very few minutes during the course of an entire year. In fact, during most years the majority of observers will have nothing whatever to record.

The following copy of the question card now in use may interest those who have not seen it:

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU
(SEISMOLOGY).

Cross out words and parts not applicable, and fill in all remaining spaces. Use other side, if desired, for additional description and information.

Date of earthquake: ....., 19....
Time of beginning (use railroad time): Hour, ... min., ..., a. m., p. m.
Location of observer: {On mountain, hill, plain, in valley. Outdoors, indoors, 1st, 2d, 3d, ... floor. / State ....., town ..... / Street ....., No. ..... / If in country, distance ....., direction..... from ..... (nearest P. O. or town).}
What doing: Lying down, sitting, standing, walking, ...
Onset of shocks: Abrupt, rapid, gradual.
Nature of shocks: Bumping, rocking, trembling, twisting, ...
Intensity (give number, see scale on other side): .....
Number of shocks during earthquake: .....
Duration of each: .....
Direction of vibration: N.–S.; NE.–SW.; E.–W.; SE.–NW.
Sounds: No, yes. Before, with, after shocks. Faint, loud, rumbling, rattling.
Felt by: One, several, many.
Name of observer: .....
Address of observer: .....

[On back of card.]

EARTHQUAKE INTENSITIES. (Adapted Rossi-Forel.)

1. Felt only by an experienced observer, very faint.
2. Felt by a few persons at rest, faint.
3. Direction or duration appreciable, weak.
4. Felt by persons walking. Doors, etc., moved.
5. Felt by nearly everyone. Furniture moved.
6. Bells rung, pendulum clocks stopped. Alarm.
7. Fall of plaster, slight damage. Scare.
8. Fall of chimneys, walls cracked. Fright.
9. Some houses partly or wholly wrecked. Terror.
10. Buildings ruined, ground cracked. Panic.

Avoiding seismic breaks, however, is not the only method of minimizing earthquake dangers and disasters. The injury to buildings, and through this injury the danger to life, depends not alone upon the severity of the shock but also upon the buildings themselves, their size, height, material, struts, relation of one portion to another, and all else that determines both strength and stability under the stress of an earthquake's peculiar motions.

Investigations of structural stability under earthquake shocks clearly are of the greatest practical importance to many parts of the world, including some of the best portions of our own country. But such studies presuppose a full knowledge of exactly what occurs when the crust is shaken by an earthquake. In short to determine how a building must be constructed best to resist a shake, the nature of the shake itself must first be known. Many and detailed instrumental analyses of earthquake shocks must be obtained and studied if we would seriously undertake to solve the structural problems every disastrous earthquake forces upon our attention.

The location of weak geologic faults and the design of more or less shock proof structures are two of the eminently practical applications of seismology. But neither can progress far or safely without the guidance of physical laws and the check of mathematical equations, for here, as in all other cases, use of knowledge awaits its possession; art follows science; sound theory determines safe practice.

Table 1, containing noninstrumental reports of earthquakes for December, 1914, presumably needs no detailed explanation.

Table 2, giving instrumental data obtained by the Marvin seismograph at Washington, D. C., from October 12, when instrument was restored to operation, to December 31, 1914, follows the international usage, according to which symbols have the following meaning:

CHARACTER OF THE EARTHQUAKE.

I=noticeable. II=conspicuous. III=strong.
d=(terrae motus domesticus)=local earthquake (sensible or felt).
v=(terrae motus vicinus) =near earthquake (under 1,000 km.).
r=(terrae motus remotus) =distant earthquake (1,000 to 5,000 km.).
u=(terrae motus ultimus) =very distant earthquake (over 5,000 km.).

EXAMPLES.—I_d indicates a local earthquake of small intensity but nevertheless sensible to individuals. III_r indicates a distant earthquake, the record of which shows motions of considerable amplitude.

PHASES.

P =(undae primae)=first preliminary tremors.
PRn=P waves reflected n times at the earth's surface.
S =(undae secondae)=second preliminary tremors.
SRn=S waves reflected n times at the earth's surface.
PS =transformed waves; longitudinal (P) to transversal (S), or vice versa.
L =(undae longae)=long waves in principal portion.
M =(undae maximae)=greatest motion in principal portion.
C =(coda)=trailers.
F =(finis)=end of sensible disturbance.
i =(impetus)=beginning.

NATURE OF THE MOTION.

e =(emersio)=appearance.
T=period=twice time of oscillation.
T=period of instrument.
A=amplitude of earth movement, reckoned from zero line.
E or N attached to a symbol signify E–N or N–S component respectively, thus:
A_E E–W component of A, A_N N–S component of A } measured in microns (μ), $\frac{1}{1000}$ millimeter.
V=magnification of instrument.
ϵ =damping coefficient.

SEISMOLOGICAL REPORTS FOR OCTOBER, NOVEMBER AND DECEMBER, 1914.

TABLE 1.—*Noninstrumental earthquake reports, December, 1914.*

Day.	Approximate time. Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
	h. m.	CALIFORNIA.	° ′	° ′			m. s.			
10	8 1	Eureka	40 48	124 11	2	1	5		Shook wooden buildings.	U. S. Weather Bureau.
28	10 43	Arbolado	36 15	121 47	2	1	Few.			Forest Service.
	10 43	Campbell	37 17	121 57	2	1	2			F. M. Righter.
	10 43	Coyote	37 14	121 44	4	3	4	Rumbling...	Shook buildings.	Stanley Sharp.
	10 43	Gilroy	37 08	121 28	2	1	25			Agent, S. P. Co.
	10 43	Oakland	37 47	122 15	2–3	1	½			C. Burckhalter.
	10 43	San Francisco	37 48	122 26	3	1	5			U. S. Weather Bureau.
	10 43	....do	37 47	122 26	3	2	2			Dominican Sisters.
	10 43	Santa Cruz	36 57	122 02	5	1	3		Shook buildings.	W. R. Springer.
	10 43	Watsonville	36 55	121 46	4	2	20	Rumbling...		Spreckels Sugar Co.
28	8 6	Cahuilla	33 32	116 43	2	1	1	.....do.....		Dr. W. L. Shawk.
29	10 00	Aguanga	33 26	116 51	5	2				Forest Service.
	10 00	.....do	33 26	116 51		2	2			Paul Thomsen.
	10 00	Mesa Grande	33 11	116 42	3	1	14	Rumbling...		E. H. Davis.
	10 00	La Jolla	32 51	117 16	2	1	8	.....do.....		Ben Amigo.
29	12 00	Aguanga	33 26	116 51	2	1				Forest Service.
	12 00	La Jolla	32 51	117 16	2	1				Ben Amigo.
		SOUTH CAROLINA.								
23	11 55	Summerville	33 05	80 14	1	1				Miss E. H. Gadsden.
		TEXAS.								
30	1 00	Anderson	30 31	95 55	5	1	Few.	Rumbling...	(Explosion?)	Dr. Oscar Davis.
		UTAH.								
14	5 30	Enterprise	37 35	113 50	5	1	30	Rumbling...		Jas. E. Hall.
21	5 25	Hurricane	37 15	113 25	2	1				Amos Workman.
21	5 25	Pine Valley	37 24	113 30	3	1	15	Faint		I. M. Gardner.
21	5 25	Pinto	37 33	113 31	2–3	1	10	Rumbling...		J. H. Harrison.

TABLE 2.—*Instrumental report October, November, and December, 1914.*

[Washington, D. C. Latitude 38° 54′; longitude, 77° 03′; elevation, 21 m. Time: Mean Greenwich, midnight to midnight. Nomenclature: International. Instrument: Marvin (vertical pendulum). From Oct. 12 to Dec. 31, 1914.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1914.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 22	I_r	eP_N	6 59 54	5		2	1,400	Phase not well marked.
		S_N	7 02 21	10		6		
		L_N	7 03 05	8		4		
		F	7 11 30					
23	II_u	eP_N	6 38 09	5		16	5,920	Some doubt about phase.
		$iN_?$	6 41 21					
		S_N?	6 45 41					
		L_N	6 57 50	20				
		L_N	7 07 45	40				
		L_N	7 21 30	40				
		L	7 28 25	25		7		
		L	7 41 00					
		F	8 04 00					
Nov. 9	I?	L	1 28 40					
10	II_d	eP_N	11 24 22	4			600	
		S	11 25 28	4				
		L	11 25 50					
		M_N	11 26 12	7		18		
		F	11 37 00					
18	II_r	P_N	9 45 27	2½		1	4,175	P not on E–W. S not on N–S except as trace.
		iS_E	9 51 24	8		10		
		L_E	9 54 13	20				
		M_E	9 56 10	10		13		
		F	10 28 00					
1914.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 24	III_r	P_N	12 12 17	3			3,640	
		S_N	12 17 43	8				
		M	12 17 56	8	82	84		
		iSR_2	12 20 59	8				
		M	12 21 07		110	136		
		F	14 04 00					
Dec. 4	I_v	eP_N?	22 46 46				770?	Phases not distinct.
		S	22 48 10	6				
		L	22 51 00	10				
		F	22 52 00					
20	II_u	P	14 27 20	3			8,000	Phases not distinct.
		PR_E	14 34 17					
		PR_N	14 34 17					
		S_E	14 36 40	8				
		S_N	14 36 40					
		L_N	14 52 45	45				
		F	16 00 00					
25	II_r	eP_N	3 46 27	2			2,160	
		iS_E	3 50 04					
		L_E	3 52 44	13				
		M_N	3 56 40			14		
		F	4 15 00					

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Allahabad. Meteorological office.
Administrative report of the meteorologist at Allahabad, for the year 1913–1914. Allahabad. 1914. 4 p. f°.
Brief sketch of the meteorology of the United Provinces [of Agra and Oudh], and adjacent parts of Rajputana and the Punjab, for the year 1913. Allahabad. 1914. 7 p. f°.

Amur. Meteorologicheskago bîûro.
Izvîestîîâ. [Bulletin.] Vypusk 1–2, 1913–1914. Blagovieschensk. 1913–1914. 2 v. 8°. [Text in Russian.]

Bergedorf. Hamburger Sternwarte.
Meteorologische Beobachtungen im Jahre 1913. Hamburg, 1914. 49 p. 4°.

Bok, & Motz, Th.
Kleine Wetterkunde für Schule und Haus. Gebweiler. 1914. 55 p. 8°.

Egypt. Meteorological service.
Rains of the Nile basin and the Nile flood of 1912. Cairo. 1914. 104, xii p. maps. 4°. (Survey department paper no. 32.)

Great Britain. Board of trade.
Report on the work carried out by the S. S. "Scotia," 1913. [Ice observations, meteorology, and oceanography in the North Atlantic ocean.] London. 1914. 141 p. f°. [With separate volume of maps, charts, and diagrams.]

Hesse. Grossherzogliches hydrographisches Bureau.
Deutsches meteorologisches Jahrbuch für 1913. Hessen. 13. Jahrgang. Darmstadt. 1914. (16), 65 p. map. f°.

Hörbiger, Hanns.
Wirbelstürme, Wetterstürze, Hagelkatastrophen und Marskanal-Verdoppelungen. Eine auszugsweise Teilerklärung aus dem einheitlich durchgearbeiteten Grundgedanken eines kosmischen Neptunismus. Kaiserlautern. 1913. xiv, 77 p. 4°.

Huntington, Ellsworth.
The solar hypothesis of climatic changes. 477–590 p. 4°. (Reprinted from the Bulletin of the Geological society of America, v. 25. Published November 2, 1914.)

Lindenberg. K. Preussisches aeronautisches Observatorium.
Arbeiten, 1913. 9. Band. Braunschweig. 1914. xlviii, 544 p. f°.

Lurquin, Constant.
Meteorología Boliviana. [Sucre. 1914.] 29 p. 8°. [Describes the "Observatorio meteorológico del Instituto médico Sucre" and the proposed national meteorological service for Bolivia.]

Moore, Henry Ludwell.
Economic cycles: their law and cause. New York. 1914. viii, 149 p. 8°. [Contains chapters on cycles of rainfall and the crops.]

Murphy, Robert Cushman. *ed.*
A report of the South Georgia expedition. [Brooklyn.] 1914. 43–102 p. 5 plates. 4°. (Museum of the Brooklyn institute of arts and sciences. Science bulletin, vol. 2, no. 4.) [Climate, p. 55–59.]

Netherlands. K. Meteorologisch Instituut.
Monthly meteorological data for ten-degree squares in the Atlantic and Indian oceans. Computed from international logs and observations. 1. 1913. Utrecht. 1914. 2 pts. f°. ([Publication] no. 107.)
Monthly meteorological data for ten-degree squares in the Atlantic and Indian oceans. Computed from Swedish and Dutch observations 1900–1912, and from International observations January–June 1913. Utrecht. 1914. iv, 24 p. f°. ([Publication] no. 107A.) [Gives monthly values for each year from 1900 to June 1913, from which normals may be computed for comparison with current values hereafter published.]

Nichols, John Benjamin.
The influence of atmospheric conditions on the vital processes. 24 p. 12°. (Reprinted from the Virginia medical semi-monthly, Dec. 11, 1914.)

Parma. Ufficio idrografico del Po.
Istruzioni per la misura delle precipitazioni meteoriche. Parma. 1913. 3 pts. 4°. [Pt. 1. Pluviometro comune; pt. 2. Pluviografo; pt. 3. Pluvionivometro.]
Istruzioni per la misura della temperatura dell' acqua dei fiumi. Parma. 1913. 6 p. 4°.
Il pluvionivometro totalizzatore dell' Ufficio idrografico del Po. Cenni illustrativi e istruzioni. Parma. 1914. 7 p. plate. 4°.

Philipp, H[ans Hermann].
Ergebnisse der W. Filchnerschen Vorexpedition nach Spitzbergen 1910. Gotha. 1914. vi, 79 p. 15 plates. 4°. (Ergänzungsheft Nr. 179 zu Petermanns Mitteilungen.) [Contains contributions by E. Barkow; viz, "Meteorologische Beobachtungen im innern Spitzbergens," "Luftelektrische Messungen in Spitzbergen und im nördlichen Eismeer," etc.]

Piancastelli, Carlo.
Pronostici ed almanacchi. Studio di bibliografia romagnola. Roma. 1913. 121 p. 8°.

Pontificia accademia romana dei Nuovi Lincei.
Memorie. v. 31. Roma. 1913. 339 p. 4°.

Reed, William Gardner.
Climatic provinces of the western United States. 19 p. 8°. (Reprinted from the Bulletin of the American geographical society, v. 47, January, 1915.)

Ruppel, Sigwart.
Blitzschutz von Eisenbetonbauten. Vortrag gehalten auf der 17. Hauptversammlung des "Deutschen Beton-Vereins" in Berlin. [Berlin. 1914.] 7 p. f°. (Sonderabdruck aus "Deutsche Bauzeitung." Mitteilungen über Zement, Beton- und Eisenbetonbau, 11. Jahrgang 1914, No. 6, 8, und 9.)
Vereinfachte Blitzableiter. 3. vollständig umgearbeitete Auflage. Mit 80 Textfiguren. Berlin. 1914. iv, 134 p. 16°.
Vereinfachung des Gebäudeblitzschutzes. Vortrag gehalten im Elektrotechnischen Verein in Wien am 18. März 1914. Wien. [1914.] 5 p. f°. (Sonderabdruck aus "Elektrotechnik und Maschinenbau," Zeitschrift des Elektrotechnischen Vereines in Wien, Heft 25, 1914.)

Schmidt, Alb.
Beiträge zum Klima von Wiesbaden. Wiesbaden. 53–66 p. 8°. (Sonderabdruck aus den Jahrbüchern des Nassauischen Vereins für Naturkunde in Wiesbaden, 66. Jahrgang, 1913.)

Shaw, Harry B.
An improved cog psychrometer. 183–185 p. 4°. (Reprinted from the Plant world, v. 17, no. 6, June, 1914.)

Spain. Servicio central hidráulico.
Instrucciones para la previsión y anuncio de crecidas. Primera edición. Madrid. 1914. 111 p. 5 plates. 4°.

Steadworthy, A.
Spectrum of lightning. 345–348 p. 5 plates. 8°. (Reprinted from the Journal of the Royal astronomical society of Canada. September–October, 1914.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American geographical society. Bulletin. New York. v. 47. January, 1915.
Reed, William Gardner. Climatic provinces of the western United States. p. 1–19.

Astrophysical journal. Chicago. v. 11. December, 1914.
Fowle, F[rederick] E[ugene]. Avogadro's constant and atmospheric transparency. p. 435–442.

Geographical Journal. London. v. 45. January, 1915.

Mediæval climate. p. 82. [Abstract of memoir by A. Norlind.]

Great Britain. Meteorological office. Geophysical memoirs. London. v. 1. 1913.

Fairgrieve, J. On the relation between the velocity of the gradient wind and that of the observed wind; with a preface by W. N. Shaw. p. 189–207. (No. 9.)

Hepworth, M. W. Campbell. The effect of the Labrador current upon the surface temperature of the North Atlantic; and of the latter upon air temperature and pressure over the British Isles. Part 2. p. 211–220. (No. 10.)

Imperial institute. Bulletin. London. v. 12. July–September, 1914.

McClellan, F. C. Agricultural resources of the Zanzibar protectorate. p. 407–429. [Climate, p. 409–410.]

Nature. London. v. 94. December 17, 1914.

Aitken, John. Forests and floods. p. 420.

Atmospheric pollution. p. 433–434.

Popular science monthly. New York. v. 85. December, 1914.

Ward, Robert DeC[ourcy]. The war and the weather during the first three months of the war. p. 604–613.

Royal Asiatic society. North China branch. Journal. Shanghai. 1914.

Edgar, J. Huston. Notes on temperatures in high altitudes on the Tibetan border. p. 57–64. [The author finds remarkably mild winter weather and light snowfall to prevail at high altitudes in eastern Tibet.]

Scottish meteorological society. Journal. Edinburgh. 3 ser. v. 16. no. 31. 1913.

Watt, Andrew. Robert Traill Omond, LL. D. p. 293–302. [With portrait and list of writings.]

Wedderburn, E. M. Sir John Murray, K. C. B., F. R. S. p. 303–304. [With portrait.]

Dines, W[illiam] H[enry]. Cyclones and anticyclones. p. 304–312.

Watt, A[ndrew]. The annual rainfall of Scotland and the limits within which it fluctuates. p. 312–319.

Bennett, J. B. The practical value of long-period rainfall observations. p. 320–328.

Smith, James. The relation of rainfall to the depth of water in a well. p. 329–335.

Shaw, W[illiam] N[apier]. Pressure in absolute units. p. 336–341. [Reprint from Monthly weather review.]

Tokyo mathematico-physical society. Tokyo. 2 ser. v. 7. October, 1914.

Nagaoka, H[antaro]. Certain phenomena accompanying the propagation of electric waves over the earth's surface and the ionized layer of the atmosphere. p. 403–412.

Académie des sciences. Comptes rendus. Paris. tome 159. 14 décembre 1914.

Trillat, A., & Fouassier. Influence de la radioactivité de l'air sur les gouttelettes microbiennes de l'atmosphère. p. 817–819.

Archives des sciences physiques et naturelles. Genève. tome 38. 15 novembre 1914.

Maurer, J[ulius]. Nouvelles études sur l'évaporation à la surface des lacs et spécialement des lacs Zuricois. p. 329–334.

Gruner, P[aul]. La photométrie de la lumière pourprée. p. 335–336.

Annalen der Hydrographie und maritimen Meteorologie. Berlin. 42. Jahrgang. Heft 12. 1914.

Dickermann, Carl. Die Windverhältnisse an der vorpommerschen Küste mit besonderer Berücksichtigung der Anemometer-Beobachtungen von Wustrow 1887 bis 1910. p. 629–648.

Burggraf, P. Orkan zu Port Amelia (Portugiesisch Ostafrika) am 12. April 1914. p. 670–672.

Annalen der Physik. Leipzig. 4. Folge. Band 45. Heft 7. 1914.

Aganin, M. Über die Elektrizitätsentwickelung bei abreissenden Wassertropfen. p. 1003–1012. [Mentions application to Simpson's thunderstorm hypothesis.]

Geographische Zeitschrift. Leipzig. 20. Jahrgang. 9/10 H. 1914.

Klute, Fritz. Forschungen am Kilmandscharo im Jahre 1912. p. 496–505. [Climate, p. 500–502.]

Nordenskjöld, Otto. Einige Züge der physischen Geographie und der Entwickelungsgeschichte Süd-Grönlands. p. 505–524. [Climate, p. 510–514.]

Lindenberg. K. Preussisches aeronautisches Observatorium. Arbeiten. Braunschweig. 9. Band. 1913.

Reger, Josef. Die Werte des absoluten Massystems und ihre praktische Bestimmung in den Beobachtungen des Königlichen aeronautischen Observatoriums. p. 343–347.

Peppler, Albert, & Stuchtey, Karl. Absolute Messungen der Sonnenstrahlung auf Hochfahrten in den Jahren 1912 und 1913. p. 349–364.

Peppler, Wilhelm. Messungen der Intensität der Sonnenstrahlung. p. 365–370.

Jaeger, Manfred. Anwendungen der Hydrodynamik auf meteorologische Probleme. p. 383–392.

Tetens, Otto. Über die Kombinierung von Wolkenmessungen. p. 393–409.

Bongards, Hermann. Über eine Beziehung zwischen Nebelhäufigkeit und Gehalt der Atmosphäre an radioaktiven Zerfallsprodukten. p. 411–415.

Tetens, Otto. Eine neue Konstruktion des Weberschen Polarisationsphotometers mit besonderer Berücksichtigung zenitaler Messungen. p. 417–433.

Peppler, Wilhelm. Die aerologischen Verhältnisse der freien Atmosphäre bei typisch zyklonaler Wetterlage. p. 435–446.

Peppler, Wilhelm. Bearbeitung der doppelten und dreifachen Pilotvisierungen im Jahre 1913. p. 447–470.

Reger, Josef. Über die elastische Nachwirkung bei Bourdonbarometern. p. 471–474.

Tetens, Otto. Die Drachentechnik am Königlichen aeronautischen Observatorium. p. 475–505.

Bongards, Hermann. Bericht über den Wetterdienst für Luftfahrer im Jahre 1913. p. 507–510.

Meteorologische Zeitschrift. Braunschweig. Band 31. November 1914.

Busch, Friedr[ich]. Beobachtungen über die Nachwirkung der grossen atmosphärischen Trübung des Jahres 1912. (Dritte Mitteilung.) p. 513–522.

Krause, Gottlob Adolf. Klima von Salaga (Hinterland der Goldküste.) p. 522–531. [Abstract by J. v. Hann.]

Staikoff, St. D. Die Fehlerrechnung in der Klimatologie. p. 532–545.

Hann, J[ulius] v. Häufigkeit entgegengesetzter Änderungen des Luftdruckes und der Temperatur auf dem Sonnblickgipfel und zu Salzburg. p. 545–548.

P[aul] Range über das Klima der deutschen Süd-Kalahari. p. 553–555.

Meissner, Otto. Über die Existenz der Eisheiligen. p. 556–557. [Abstract.]

Naturwissenschaften. Berlin. 2. Jahrgang. 6. November 1914.

Sieveking, H[ermann]. Ein Radiumblitzableiter. Nach dem französischen Original von Dr. B. Szilard, Paris. p. 973–977.

Petermanns Mitteilungen. Gotha. 60. Jahrgang. 1914.

Robitzsch, Max. Eis in und um Spitzbergen. p. 187–190. (Oktober.)

Schoy, C[arl]. Das Problem des Büsserschnees. p. 209–211. (November.)

Prometheus. Berlin. Jahrgang 26. 1914.

Bechstein, O. Luftprüfer Aeronom. p. 88–89. (Nov. 7.)

Greding, Wilhelm. Ein Stück Arktis in Bayern. p. 134–136, 148–150 (Nov. 28, Dez. 5). [Freezing of Bavarian lakes in winter of 1913–1914. Character of ice.]

Wetter. Berlin. 31. Jahrgang. November 1914.

Thraen, A[ugust]. Die Niederschlagsverhältnisse auf der nördlichen und östlichen Abdachung des Sudetensystems, dargestellt nach 20 jährigen streng gleichzeitigen Beobachtungen. p. 241–250.

Meissner, Otto. Über die Zuverlässigkeit der "Wetteraussichten für mehrere Tage." p. 250–251.

Freybe, Otto. Tiefdruckwirbel über Deutschland. p. 252–253.

Pflugk, Franz. Schneesterne und Eisblumen. p. 261–264.

Zeitschrift für Gletscherkunde. Berlin. Band 8. September 1914.

Workman, William Hunter. Nieve penitente and allied formations in Himalaya, or surface-forms of névé and ice created or modeled by melting. p. 289–330.

Società sismologica italiana. Bollettino. Modena. v. 18. No. 1–2. 1914.

Oddone, E[milio]. Sulle recenti variazioni di livello marino della regione Mediterranea centrale attribuite ai bradisismi. p. 9–81.

Malladra, Alessandro. La pioggia sul Vesuvio nel periodo 1863–1913. p. 87–167.

NOTES FROM THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Professor in charge of Library.

ORIGIN OF THE WORD "BLIZZARD."

In the third edition of Prof. Hann's "Handbuch der Klimatologie," Band 3, page 399, it is stated that:

Die grossen Schneestürme und Schneewehen, welche durch das Einbrechen der kalten NW-Winde auf der Rückseite eines Barometerminimums zuweilen eintreten, werden in Nordamerika "Blizzards" genannt. Henry Ellis, der 1746 in York Factory überwinterte, soll dieses Wort für das dichte Schneetreiben bei kalten NW-Stürmen zuerst gebraucht haben.

The above statement that the word "blizzard" was used by Henry Ellis in the description of his voyage to Hudson Bay was evidently based upon the following passage in Greely's "American Weather," page 222:

One of the first to mention the *blizzard* was Henry Ellis, who made a voyage to Hudson Bay in the ship *California* in the year 1746.

Gen. Greely's statement is ambiguous. He did not intend to convey the impression that the *word* "blizzard" was used by Ellis, but merely to state that Ellis described the type of storm now known as "blizzard" without calling it by any name.

As a matter of fact, the word "blizzard" is not known to have been used in a meteorological sense earlier than about 1860. Many efforts have been made to trace the history of this word in its meteorological application without success.[1]

[1] See in this connection MONTHLY WEATHER REVIEW, January, 1899, 27:18, and December, 1898, 26:562.—EDITOR.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

By P. C. DAY, Climatologist and Chief of Division.

Pressure.—The distribution of the mean atmospheric pressure over the United States and Canada and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

The mean atmospheric pressure for the month as a whole was below normal in the South Atlantic and east Gulf States, the middle and southern portions of the Mountain districts of the West, and thence westward to the Pacific coast, the greatest minus departures appearing in central and northern California. Over all other portions of the country the means were above the normal for the month, with especially marked plus departures over northern districts from the Atlantic to the Rocky Mountains, in the lower Missouri Valley and Central Plains States, and also over the Canadian Provinces.

During the first day or two of the month high pressure obtained quite generally throughout the country, save over the Pacific Coast States, where relatively low readings were recorded, but from about the 3d to the end of the first decade barometric conditions were unsettled over most districts, with tendencies to relatively low readings. Extensive high pressure over eastern districts during the first few days of the second decade was followed by a marked depression that moved rapidly from the Gulf to the Canadian Maritime Provinces on the 13th–14th, giving unusually low barometer readings in passing over the northeastern States. With the disappearance to sea of the above-mentioned storm, rather marked and extensive high pressure covered most districts during the following few days, but near the close of the second decade conditions again became unsettled, the weather map of the 19th showing four distinct storm centers. During the first half of the third decade relatively high pressure was the rule over most districts, but on the morning of the 29th a storm of marked energy covered the Mississippi Valley and moved thence northeastward to the Gulf of St. Lawrence by the following day. The month closed with generally high pressure and clear skies prevailing in most districts.

The distribution of the highs and lows was such as to favor the frequent occurrence of winds from a northerly direction over most districts east of the Rocky Mountains, while to the westward the usual variable winds prevailed.

Temperature.—Warm weather, for the season of the year, marked the first few days of the month from the Mississippi Valley eastward, and moderate temperatures prevailed thereafter until about the end of the first decade in most eastern districts.

By the 10th strong high pressure had moved into the Dakotas, and considerably colder weather overspread much of the Mountain and Plateau region. The cold area advanced rapidly southward and eastward, with freezing temperatures over the east Gulf and South Atlantic States and frost as far south as central Florida. However, there was a quick return to warmer weather over these districts, but lower temperatures had again set in over the Mountain regions of the West and the Great Plains States, and by the morning of the 14th low temperatures had again overspread the central valleys and Southern States, and it continued cold in the far West. By the morning of the 16th the cold wave had overspread nearly all portions of the country with temperatures below zero as far south as central Kansas and the mountain districts of Virginia, and below freezing over the Gulf and South Atlantic coasts.

Beginning about the 21st cold weather again overspread the Mountain districts of the West, and during the following few days it extended to practically all portions of the country, with unusually low temperatures prevailing along the northern border. From the 27th to the 29th there was a general moderation, but during the last days of the month colder weather again overspread the central and eastern States, while in other portions of the country there was a tendency to more seasonable temperatures.

For the month as a whole the average temperature was below the normal in all districts, save in extreme southern Florida. Throughout the central valleys and in the Plateau region the month was among the coldest Decembers of record.

Day temperatures were unusually high on the 1st and 2d at points in the Lake region and North Atlantic States, but otherwise they were within the limits of previous years. At points in North Dakota they did not go above freezing during the entire month.

Minimum temperatures below freezing occurred over all portions of the country, save in central and southern Florida, extreme southern Texas, southwestern Arizona, and along the Pacific coast, while readings more than 30° below zero occurred at exposed points in New England, and they were somewhat lower in portions of Minnesota. During the cold waves about the middle of the month and near the end some of the lowest temperatures on record for December were reported in the middle Mississippi and Ohio Valleys and over the northeastern States.

Precipitation.—No well-defined storm area crossed the country during the first decade of the month, but during this period weather conditions were unsettled over most districts to eastward of the Rocky Mountains and precipitation was of more or less frequent occurrence, with some heavy rainfall during the first few days in portions of the Gulf region, more than 7 inches occurring at Houston, Tex., during the 24 hours ending at 8 a. m. of the 2d. During the above-named period pressure was likewise comparatively low in the Pacific coast region, where general and beneficial rains occurred, especially in California, where the need of moisture was beginning to be seriously felt.

During the first half of the second decade a disturbance moved rapidly eastward from the far Southwest to the east Gulf States, and thence northeastward, accompanied by precipitation over much of the country, with heavy

rain along the Atlantic coast and heavy snow in portions of the Appalachian Mountain districts, the upper Ohio Valley, the lower Lake region, and parts of New York and New England. With the passing of this storm fair weather was the rule during the following few days, but near the close of the decade weather conditions again became unsettled over much of the country, with general snow over northern districts and rain over the central and southern portion of the country east of the Rocky Mountains.

During the first half of the third decade a disturbance moved from southern California eastward across the Southern States and disappeared off the South Atlantic coast about the 26th, accompanied by snow in most central and northern districts and rain throughout the South. During the following few days no widespread precipitation occurred, but a well-defined disturbance passed from the Mississippi Valley to the Gulf of St. Lawrence during the 29th and 30th, causing general precipitation from the Plains States eastward. This storm was followed by fair weather, which prevailed generally at the close of the month.

For the month as a whole the precipitation was generous and above normal over much of the country from the Plains region eastward, some portions of those districts receiving large amounts, particularly parts of Texas, Arkansas, Mississippi, and Tennessee, where 8 inches or more occurred. Precipitation was heavy also over the southern portions of the Rocky Mountain and Plateau regions and in parts of California.

In the northern Pacific coast States, over the northern and central portions of the mountain districts of the West, the northern Plains States, and the upper Mississippi Valley the amounts were, as a rule, comparatively light and less than the monthly normal, while portions of the southeastern States, the upper Lake region, and New England likewise received less than the normal amount of precipitation for December.

GENERAL SUMMARY.

The month as a whole was cold, cloudy, and wet over the districts from the Mississippi River eastward, these conditions being especially pronounced in the east Gulf and South Atlantic States, where all farming operations were practically at a standstill and considerable damage occurred to the trucking interests on account of the frequent and severe changes in temperature and the general lack of sunshine.

Over the districts to westward of the Mississippi the month was generally cold and dry, except in the west Gulf States, California, and portions of Arizona and New Mexico, where more than the average amounts of precipitation occurred. More than the usual snow covering prevailed over the States from the Plains region eastward, and a large portion of the winter grain-growing districts was well protected during the cold periods of the month, while at the same time there was a general absence of snow over the great cattle ranges, which permitted continued grazing.

In the western Mountain regions there appears to have been considerable snow in the higher elevations of California and portions of Arizona and New Mexico, which, with good rains at the lower elevations of those States, assure a good supply of water for irrigation and other purposes during the coming spring and summer. However, elsewhere in the Mountain districts the fall of snow was light and the stored depth in the high ranges was much below the normal.

Ice formed unusually early in the month over all districts where it is expected at some time during the winter, and large supplies of excellent quality had been harvested at the end of the month, especially in the rural districts.

Average accumulated departures for December, 1914.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.			P. ct.	
New England	27.3	−2.1	− 8.5	3.28	−0.10	− 6.20	6.2	+0.1	75	− 1
Middle Atlantic	31.8	−3.2	− 1.8	4.87	+1.70	− 6.30	6.9	+1.1	78	+ 3
South Atlantic	44.9	−2.3	+ 1.7	4.26	+0.60	−11.10	7.8	+2.9	82	+ 4
Florida Peninsula	66.0	+1.2	− 4.0	5.18	+3.10	− 6.30	6.9	+2.2	85	+ 3
East Gulf	45.6	−3.5	− 6.1	4.28	−0.20	− 3.20	7.5	+2.0	79	+ 2
West Gulf	42.4	−6.7	+ 2.2	4.28	+1.40	− 3.30	7.4	+2.2	82	+ 8
Ohio Valley and Tennessee	31.4	−5.4	+ 1.2	4.72	+1.30	− 6.90	7.8	+1.5	82	+ 6
Lower Lakes	24.9	−4.3	− 7.9	3.01	+0.10	− 2.90	7.9	+0.2	80	+ 2
Upper Lakes	19.8	−4.7	+ 6.8	1.43	−0.70	− 1.90	7.5	+0.2	81	− 1
North Dakota	6.4	−5.5	+24.3	0.34	−0.30	+ 2.00	5.8	+0.4	84	+ 5
Upper Mississippi Valley	20.5	−6.9	+17.9	1.60	−0.20	− 4.50	7.0	+1.2	84	+ 6
Missouri Valley	19.6	−7.3	+25.8	1.16	+0.10	− 0.40	6.6	+1.4	83	+ 8
Northern Slope	17.2	−6.5	+19.4	0.41	−0.50	− 2.30	5.7	+0.5	86	+18
Middle slope	24.9	−8.1	+20.6	0.95	+0.20	− 3.90	5.9	+1.8	78	+12
Southern slope	37.0	−6.8	+ 4.0	1.25	+0.40	+ 6.30	6.2	+1.2	80	+14
Southern Plateau	37.1	−5.0	+ 2.5	2.10	+1.50	+ 1.10	4.7	+1.5	76	+30
Middle Plateau	24.4	−6.9	+ 5.3	0.50	−0.50	− 0.90	5.6	+0.8	75	+ 5
Northern Plateau	23.8	−8.2	+13.7	0.65	−1.10	− 2.00	6.4	−0.4	78	− 2
North Pacific	39.1	−2.5	+14.7	2.36	−5.60	− 2.50	6.7	−1.1	81	− 5
Middle Pacific	45.2	−3.2	+ 4.5	5.30	+0.90	− 1.90	6.0	+0.6	81	0
South Pacific	50.8	−2.2	+19.7	3.43	+1.30	+ 3.50	5.8	+1.5	76	+ 7

Maximum wind velocities, December, 1914.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		Mi./hr.				Mi./hr.	
Block Island, R. I.	6	64	ne.	Mt. Weather, Va.	21	54	nw.
Do	7	71	ne.	Do	30	70	nw.
Do	8	60	ne.	Mt. Tamalpais, Cal.	19	51	nw.
Do	13	60	se.	Do	21	58	n.
Do	14	56	se.	Do	22	54	n.
Do	22	53	w.	Nantucket, Mass.	6	56	ne
Buffalo, N. Y.	14	72	w.	Do	7	68	ne
Do	15	60	sw.	Do	14	60	se.
Do	19	60	w.	New York, N. Y.	13	59	s.
Do	21	78	sw.	Do	14	62	sw.
Do	22	72	sw.	Do	20	54	nw.
Do	23	50	w.	North Head, Wash.	30	50	se.
Do	29	58	sw.	Do	31	52	se.
Do	30	66	sw.	Point Reyes Light, Cal.	2	53	s.
Canton, N. Y.	21	53	w.	Do	9	64	s.
Cheyenne, Wyo.	31	56	w.	Providence, R. I.	14	50	se.
Duluth, Minn.	29	53	nw.	Tatoosh Island, Wash.	7	57	e.
Eastport, Me.	14	70	se.	Do	8	53	e.
Mt. Weather, Va.	19	52	nw.				
Do	20	56	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data, as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Summary of temperature and precipitation, by sections, December, 1914.

Section.	Temperature (°F.).								Precipitation (in inches and hundredths).					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
Alabama	43.5	−2.8	Wetumpka	80	1	Florence	0	16	5.06	+0.45	Bridgeport	9.63	Ozark	1.50
Arizona	41.8	−1.7	Phoenix (1)	79	4	4 stations	−13	14†	3.71	+2.94	Pinal Ranch	10.86	Astec	0.27
Arkansas	36.1	−6.2	Brinkley	70	2	Mammoth Springs	−11	15	6.26	+2.24	Arkadelphia	9.48	Rison	2.60
California	41.8	−4.9	King City	92	11†	Tamarack	−22	22	5.00	+0.97	Delta	17.60	Indio	0.17
Colorado	20.0	−4.4	Two Buttes	68	2	Gunnison	−27	22	0.78	−0.47	Cumbres	4.69	3 stations	T.
Florida	59.4	+0.6	3 stations	88	3†	Bristol	21	16	4.46	+1.65	Newport	7.78	Mount Pleasant	1.83
Georgia	45.2	−1.7	2 stations	79	4†	Ramhurst	5	16	4.49	+0.32	Ramhurst	10.44	Abbeville	1.78
Hawaii (November)	71.4	.....	2 stations	90	11	3 stations	50	21†	9.58	.....	Hakalau, Hawaii	52.77	2 stations	0.00
Idaho	19.6	−6.7	Glenns Ferry	63	1	Pierson	−33	14	0.66	−0.97	Avery	1.88	Payette	0.06
Illinois	24.1	−6.3	Anna	69	2	Lincoln	−29	26	2.41	+0.27	Chester	4.88	La Salle	1.38
Indiana	26.4	−5.1	Rome	70	2	Salem	−20	15	3.05	+0.19	Vevay	5.90	Veedersburg	1.45
Iowa	15.7	−8.2	Keokuk	65	1	Iowa Falls	−31	26	1.30	+0.08	Tipton	2.24	Le Mars	0.57
Kansas	23.6	−8.4	2 stations	64	1	Smith Center	−20	21	0.76	−0.13	Oswego	2.40	Coldwater	0.21
Kentucky	32.8	−4.7	Beaver Dam	70	1	2 stations	−16	15	5.19	+1.40	Alpha	9.45	Maysville	3.53
Louisiana	46.8	−4.6	Reserve	82	3	Antioch	13	15	5.15	+0.68	Lake Charles	12.13	Napoleonville	1.95
Maryland & Delaware	31.9	−2.7	College Park, Md	68	2	Deer Park Md	−30	26	4.63	+1.12	Millsboro, Del	8.16	Grantsville, Md	1.82
Michigan	21.4	−3.3	Flint	61	1	Vassar	−27	26	1.84	−0.28	Benzonia	4.95	Iron Mountain	0.27
Minnesota	9.0	−7.3	Lynd	55	4	Campbell	−38	25	0.44	−0.33	Milan	1.35	2 stations	0.05
Mississippi	42.7	−4.9	Leakesville	73	1	Austin	8	15	5.75	+0.56	Malone	9.68	Bay St. Louis	3.52
Missouri	26.8	−7.1	Doniphan	68	2	Steffenville	−18	26	2.48	+0.31	New Madrid	5.84	Tarkio	0.57
Montana	15.8	−7.6	3 stations	57	3†	Bowen	−34	17	0.38	−0.35	Flathead Creek	1.66	2 stations	T.
Nebraska	16.9	−9.1	2 stations	61	3†	Hay Springs	−27	16	0.75	+0.01	Fullerton	1.74	Hershey	0.11
Nevada	24.5	−7.1	Logan	69	4	Carlin	−27	21	0.54	−0.50	Marlette Lake	2.28	Imlay	0.02
New England	24.4	−2.1	New London, Conn	67	4	Van Buren, Me	−42	25	3.04	−0.24	Nantucket, Mass	6.73	Bethlehem, N. H	0.65
New Jersey	31.1	−2.0	4 stations	66	3	Culvers Lake	−12	27	5.86	+1.96	Tuckerton	9.12	Sussex	2.99
New Mexico	30.8	−2.3	Tucumcari	70	1	2 stations	−21	14†	1.94	+1.33	Noria	8.02	Cimarron	0.22
New York	24.2	−1.8	De Ruyter	74	2	Old Forge	−43	26	3.26	−0.10	Adams Center	8.01	Chazy	0.80
North Carolina	39.6	−2.2	Newbern	76	1	2 stations	− 2	15†	7.10	+2.80	Globe	14.33	Wilmington	2.39
North Dakota	5.3	−7.6	2 stations	57	3†	2 stations	−41	25	0.50	−0.01	Langdon	2.00	3 stations	0.10
Ohio	27.0	−4.2	Syracuse	74	2	Bowling Green	−19	26	3.77	+0.98	Cadiz	7.50	Cleveland	1.57
Oklahoma	32.5	−6.7	2 stations	74	1†	Oakwood	− 5	26	2.23	+1.00	Idabel	7.54	2 stations	0.18
Oregon	30.0	−6.4	Port Orford (2)	71	23†	Beckley	−28	21	2.13	−2.90	Happy Home	17.29	Owyhee	T.
Pennsylvania	27.3	−3.0	Scranton	69	2	West Bingham	−28	26	4.63	+1.47	Philadelphia (b)	7.74	Lawrenceville	2.43
Porto Rico	76.0	+1.4	Arecibo	94	9†	Maricao	50	29	3.57	−1.49	Rio Grande El Verde	9.80	Guanica Centrale	0.00
South Carolina	43.9	−2.6	Georgetown	80	1	Clemson College	11	15	4.78	+1.35	Clemson College	11.00	Georgetown	1.51
South Dakota	13.5	−8.1	2 stations	60	3	Pollock	−37	16	0.50	−0.06	Marion	1.50	Castlewood	0.12
Tennessee	36.0	−3.8	Perryville	73	2	Erasmus	−18	15	6.86	+2.32	Charleston	10.69	Trenton	3.48
Texas	42.4	−6.2	Alice	81	2	2 stations	3	14†	3.54	+1.24	Alvin	12.19	Ochiltree	0.05
Utah	22.6	−4.2	Scipio	59	4	Scofield	−26	19	0.53	−0.38	Marysvale	2.09	Whiskey Creek	0.00
Virginia	34.3	−2.8	Callaville	72	1	Burkes Garden	−17	15†	5.38	+2.19	Buchanan	8.40	2 stations	3.46
Washington	28.1	−5.9	2 stations	62	23†	Ellensburg	−16	13	1.84	−3.18	Lake Cushman	9.06	Eltopia	0.15
West Virginia	30.3	−3.8	Cairo	70	1	2 stations	−20	16	5.46	+2.38	Phillippi	8.04	Burlington	2.58
Wisconsin	14.4	−6.0	Menominee Falls	56	1	Hatfield	−36	26	0.90	−0.44	Shullsburg	2.64	Superior	0.09
Wyoming	15.1	−5.5	Kennear	69	7	2 stations	−28	12†	0.30	−0.46	Afton	0.90	Hyattville	T.

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8. p. m., seventy-fifth meridian time daily, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values, except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading and (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity.

Chart IV.—Temperature departures. This chart presents the departures of the monthly mean temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 31 years (1883 to 1903) and are published in Weather Bureau Bulletin "R," Washington, 1908. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading, and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the night time.

Chart VII.—Isobars and isotherms at sea level and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observations, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction t_0–t, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given.

Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

[Followed by 35 charts, W. J. H. 1–35 (XLII–29 to XLII–126), illustrating article by Prof. W. J. Humphreys].

TABLE I.—*Climatological data for United States Weather Bureau stations, December, 1914.*

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
New England.							27.3	− 2.1												75	3.28	− 0.1									6.2		
Eastport	76	67	85	30.04	30.12	+ .14	23.6	− 1.7	53	1	31	−11	26	17	39	21	16	73	1.95	− 2.0	8	9,942	w.	70	se.	14	11	6	14	5.9	9.0	T.
Greenville	1,070	6	....	28.89	30.12	.....	15.8	.....	53	1	25	−19	27	7	30	.....	.....	.....	1.50	.....	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.7	9.0	
Portland, Me.	103	82	117	30.04	30.17	+ .14	24.4	− 2.7	56	3	32	− 6	26	17	29	21	13	63	2.98	− 0.7	10	7,481	n.	48	se.	14	13	7	11	5.1	8.1	3.1
Concord	288	70	79	29.85	30.18	+ .12	22.4	− 4.0	56	1	32	−20	27	12	34	.....	.....	.....	2.07	− 1.3	10	3,895	w.	28	w.	14	9	8	14	5.7	9.3	6.3
Burlington	404	11	48	29.70	30.17	+ .12	21.2	− 1.3	62	2	29	−17	26	14	27	.....	.....	.....	1.25	− 0.4	9	8,981	n.	48	s.	19	4	11	16	6.8	7.7	4.6
Northfield	876	12	60	29.18	30.17	+ .12	17.9	− 2.6	57	2	29	−32	26	6	47	15	12	82	1.19	− 1.5	7	5,233	s.	29	sw.	30	6	11	14	6.4	14.7	8.8
Boston	125	115	188	30.02	30.16	+ .11	30.4	− 1.2	62	3	37	− 2	26	24	31	27	22	74	3.46	0.0	10	8,555	w.	40	se.	14	6	11	14	6.4	4.1	0.2
Nantucket	12	14	90	30.11	30.12	+ .07	34.7	− 2.0	56	2	40	14	26	30	26	32	29	82	6.73	+ 3.1	13	14,496	ne.	68	ne.	7	5	12	14	6.8	2.2	....
Block Island	26	11	46	30.10	30.13	+ .07	34.0	− 2.6	54	3	39	6	26	29	28	31	28	79	4.98	+ 1.2	12	16,409	w.	71	ne.	7	7	5	19	7.1	1.2	....
Narragansett Pier	.....	9	.....	.....	.....	.....	31.2	− 1.3	61	3	39	− 1	26	24	34	.....	.....	.....	5.14	.....	12	.....	w.	.....	.....	.....	15	4	12	.....	0.4	....
Providence	160	215	251	29.98	30.16	+ .10	29.2	− 2.4	61	3	36	− 2	26	23	30	26	23	79	2.93	− 1.0	12	10,431	nw.	50	se.	14	11	7	13	5.8	1.5	....
Hartford	159	122	140	29.99	30.17	+ .10	28.3	− 1.5	59	3	35	− 8	27	21	27	25	20	73	3.85	+ 0.3	9	5,133	n.	27	sw.	14	8	9	14	6.2	2.5	0.8
New Haven	106	117	155	30.04	30.16	+ .09	30.4	− 1.4	63	3	37	− 1	27	24	31	26	20	68	4.87	+ 1.2	11	8,269	n.	44	ne.	7	11	7	13	5.8	3.0	T.
Middle Atlantic States.							31.8	− 3.2												78	4.87	+ 1.7									6.9		
Albany	97	102	115	30.07	30.19	+ .11	26.1	− 1.4	62	2	34	−18	27	19	35	23	19	76	1.84	− 0.7	12	5,864	s.	35	s.	19	9	8	14	6.2	6.2	0.8
Binghamton	871	10	69	29.19	30.16	+ .07	24.8	− 2.9	68	2	32	−16	27	17	40	.....	.....	.....	2.18	− 0.3	14	4,116	ne.	24	nw.	21	4	9	18	7.3	16.5	4.0
New York	314	414	454	29.81	30.16	+ .07	31.5	− 2.9	61	3	38	4	26	26	35	28	23	70	4.01	+ 0.6	11	12,511	ne.	62	sw.	14	7	7	17	6.9	2.4	....
Harrisburg	374	94	104	29.79	30.21	+ .09	29.4	− 3.4	59	3	35	1	27	24	26	26	22	75	4.63	+ 2.0	12	5,084	w.	24	w.	15	6	5	20	7.0	8.4	2.0
Philadelphia	117	123	190	30.05	30.18	+ .07	33.3	− 2.4	63	3	39	8	27	28	24	30	27	80	7.35	+ 4.3	10	8,520	nw.	31	ne.	5	7	7	17	6.5	1.0	....
Reading	325	81	98	29.82	30.20	.....	29.6	.....	62	3	35	0	27	24	22	27	22	75	5.52	+ 2.2	14	4,913	nw.	28	nw.	21	7	6	18	6.9	5.2	T.
Scranton	805	111	119	29.28	30.18	+ .08	28.0	− 1.8	69	2	35	− 3	27	21	27	25	21	76	4.19	+ 1.6	12	5,160	sw.	30	sw.	14	6	8	17	7.1	12.1	T.
Atlantic City	52	37	48	30.10	30.16	+ .06	34.4	− 2.0	60	3	40	8	26	28	29	32	28	79	8.24	+ 4.5	13	7,028	n.	40	ne.	7	8	4	19	7.1	1.2	....
Cape May	18	13	49	30.16	30.18	+ .07	34.6	− 3.4	55	2	40	10	26	29	26	33	.....	.....	6.64	+ 2.9	16	7,580	n.	38	ne.	5	6	8	17	7.2	0.7	....
Trenton	190	159	183	29.95	30.16	.....	30.6	.....	63	3	36	4	27	25	28	28	24	78	4.64	+ 1.5	13	9,636	ne.	42	ne.	7	8	6	17	6.6	2.5	....
Baltimore	123	100	113	30.06	30.20	+ .07	33.4	− 3.5	63	3	39	5	27	28	24	30	25	71	4.34	+ 1.3	11	5,747	n.	27	ne.	5	8	5	18	6.5	2.5	....
Washington	112	62	85	30.06	30.19	+ .05	32.8	− 3.3	64	2	38	2	27	27	26	30	25	76	4.49	+ 1.3	12	5,275	nw.	33	nw.	30	8	6	17	7.0	3.5	T.
Lynchburg	681	153	188	29.39	30.16	+ .02	35.0	− 3.3	65	3	42	0	27	28	30	32	27	75	4.68	+ 1.4	14	4,941	ne.	33	nw.	30	7	8	16	7.1	6.2	T.
Mount Weather	1,725	10	75	28.25	30.16	+ .03	27.0	− 4.5	58	2	32	− 1	15	22	26	25	22	83	4.22	+ 1.1	16	11,765	nw.	70	nw.	30	5	9	17	6.9	14.1	6.8
Norfolk	91	170	205	30.05	30.15	+ .02	40.0	− 3.0	67	1	45	19	26	35	25	38	35	84	4.69	+ 1.2	16	10,063	n.	48	se.	13	3	9	19	7.5	2.7	....
Richmond	144	11	52	30.02	30.18	+ .04	35.7	− 5.3	68	1	41	7	27	30	21	33	29	80	4.95	+ 2.0	19	5,343	ne.	25	w.	29	7	6	18	6.8	5.4	T.
Wytheville	2,293	40	47	27.69	30.17	+ .02	30.9	− 4.4	57	1	38	− 5	27	24	33	28	26	85	6.14	+ 2.4	16	3,824	w.	22	w.	22	10	14	7	6.6	16.2	2.0
South Atlantic States.							44.9	− 2.3												82	4.26	+ 0.6									7.8		
Asheville	2,255	70	84	27.72	30.16	.00	36.2	− 1.6	67	2	43	4	16	30	31	33	30	81	6.51	+ 2.4	15	5,891	nw.	34	e.	4	3	9	19	7.5	3.1	....
Charlotte	773	68	76	29.28	30.14	− .02	38.4	− 4.5	63	1	44	15	27	33	19	36	32	81	6.53	+ 2.7	13	4,891	ne.	32	w.	29	5	4	22	8.0	.....	.....
Hatteras	11	12	50	30.08	30.09	− .04	48.0	− 0.8	70	21	53	31	15	43	25	45	43	87	4.71	− 0.4	14	12,947	n.	49	n.	26	2	6	23	8.4	.....	.....
Manteo	12	4	46	.....	.....	.....	46.4	.....	68	19	54	26	15	39	.....	.....	.....	.....	4.17	− 1.0	9	.....	n.	.....	.....	.....	6	7	18	.....	.....	.....
Raleigh	376	103	110	29.73	30.15	.00	38.6	− 4.1	68	1	44	15	27	33	20	35	32	80	6.60	+ 3.4	13	5,672	ne.	29	ne.	25	5	4	22	7.9	T.	....
Wilmington	78	81	91	30.03	30.12	− .03	45.6	− 1.6	72	1	53	20	16	39	29	42	39	83	2.39	− 0.7	17	5,698	n.	29	w.	29	4	7	20	7.6	.....	.....
Charleston	48	11	92	30.05	30.10	− .05	48.8	− 2.5	68	25	55	28	17	43	24	45	42	81	2.35	− 0.8	13	7,921	n.	31	nw.	29	6	4	21	7.4	.....	.....
Columbia, S. C.	351	41	57	29.74	30.14	− .02	43.4	− 3.8	68	1	49	20	17	37	23	40	36	80	3.13	+ 0.2	13	4,750	ne.	25	ne.	26	6	5	20	7.3	.....	.....
Augusta	180	89	97	29.93	30.13	− .03	45.4	− 1.6	70	1	52	22	17	39	30	42	39	85	2.76	− 0.7	13	4,650	nw.	29	nw.	29	4	5	22	8.0	.....	.....
Savannah	65	150	194	30.04	30.10	− .05	49.8	− 1.5	76	25	56	27	17	43	25	46	42	81	2.49	− 0.6	14	8,133	nw.	40	w.	29	4	7	20	7.7	.....	.....
Jacksonville	43	96	129	30.04	30.10	− .04	54.6	− 0.6	78	4	62	32	12	48	23	50	47	84	5.20	+ 2.2	10	6,094	n.	37	sw.	25	3	9	19	7.7	.....	.....
Florida Peninsula.							66.0	+ 1.2												85	5.18	+ 3.1									6.9		
Key West	22	10	64	30.00	30.02	− .06	71.4	+ 1.3	83	25	76	56	12	67	19	68	66	88	6.17	+ 4.3	10	6,918	ne.	30	n.	16	8	10	13	6.2	.....	.....
Miami	25	71	79	30.02	30.05	.....	69.5	+ 1.5	80	29	75	44	12	64	23	65	64	86	4.43	+ 2.2	14	5,571	nw.	24	w.	14	5	7	19	7.5	.....	.....
Sand Key	23	39	72	29.97	30.00	− .08	72.0	.....	80	26	75	57	12	69	18	69	67	83	5.61	.....	11	11,051	ne.	48	ne.	16	8	9	14	6.2	.....	.....
Tampa	35	79	96	30.03	30.07	− .05	61.2	+ 1.7	80	1	68	37	12	54	23	57	54	85	4.93	+ 2.9	12	4,843	n.	25	e.	8	3	8	20	8.0	.....	.....
Titusville	44	6	....	30.01	30.06	.....	61.8	+ 0.1	85	4	70	36	12	54	31	.....	.....	.....	5.00	.....	20	.....	nw.	.....	.....	.....	8	4	19	6.8	.....	.....
East Gulf States.							45.6	− 3.5												79	4.28	− 0.2									7.5		
Atlanta	1,174	190	216	28.87	30.13	− .03	40.3	− 4.3	68	2	46	11	15	34	24	38	34	80	5.31	+ 0.8	15	8,122	nw.	37	w.	29	3	5	23	8.3	1.2	....
Macon	370	78	87	29.72	30.13	− .03	45.0	− 1.8	72	4	52	18	16	38	26	41	38	82	2.42	− 2.0	11	4,946	nw.	24	ne.	26	4	10	17	7.4	.....	.....
Thomasville	273	8	57	29.80	30.11	− .04	50.4	− 2.1	76	4	59	25	12	42	25	46	43	83	4.60	+ 0.9	11	3,873	nw.	19	w.	25	5	7	19	7.1	.....	.....
Pensacola	56	140	182	30.05	30.11	− .04	50.8	− 3.1	72	2	58	27	15	43	22	46	42	76	3.73	− 0.4	11	9,841	n.	44	e.	12	3	9	19	7.5	.....	.....
Anniston	741	9	57	29.33	30.15	− .01	41.4	− 2.8	72	2	48	12	15	34	29	.....	.....	.....	3.85	− 0.7	18	4,210	nw.	29	se.	13	4	4	23	8.0	0.5	....
Birmingham	700	11	48	29.38	30.17	+ .01	41.9	− 5.4	72	2	49	10	15	35	28	38	34	78	4.65	0.0	14	4,717	n.	31	se.	29	5	7	19	7.5	T.	....
Mobile	57	125	161	30.06	30.12	− .03	49.4	− 2.1	76	29	57	26	16	42	25	45	40	75	4.13	− 0.4	9	7,733	n.	47	se.	12	8	5	18	6.5	.....	.....
Montgomery	223	100	112	29.89	30.15	− .01	46.0	− 3.1	75	2	53	19	16	39	32	42	38	77	6.21	+ 1.7	14	5,001	nw.	25	w.	25	2	8	21	7.9	T.	....
Meridian	375	85	93	29.74	30.15	− .01	42.9	− 4.0	69	25	50	18	16	35	38	40	36	81	4.55	− 0.7	9	3,897	ne.	30	w.	29	5	5	21	7.6	.....	.....
Vicksburg	247	65	74	29.88	30.17	+ .02	43.2	− 6.2	69	2	50	18	15	37	25	40	37	83	3.69	− 1.3	14	4,669	ne.	26	nw.	28	7	4	20	7.4	T.	....
New Orleans	51	90	121	30.06	30.12	− .01	50.8	− 3.6	76	24	57	29	15	44	30	47	43	79	3.99	− 0.5	10	6,557	ne.	36	se.	12	4	7	20	7.6	.....	.....
West Gulf States.							42.4	− 6.7												82	4.28	+ 1.4									7.4		
Shreveport	249	77	93	29.90	30.18	+ .05	41.5	− 7.4	62	2	48	18	15	35	25	39	35	82	7.16	+ 2.8	16	4,893	nw.	28	w.	29	9	4	18	7.0	.....	.....
Bentonville	1,303	11	44	28.76	30.17	+ .04	31.2	− 6.3	60	1	38	1	15	25	29	.....	.....	.....	3.60	+ 0.8	17	3,698	n.	17	w.	29	8	2	21	7.6	9.8	....
Fort Smith	457	79	94	29.68	30.18	+ .05	35.8	− 5.9	59	1	41	10	15	30	24	33	29	80	4.06	+ 1.2	14	5,792	e.	35	nw.	29	6	3	22	7.5	1.9	....
Little Rock	357	139	147	29.80	30.20	+ .06	36.9	− 6.6	61	2	42	8	15	31	21	34	31	80	6.88	+ 2.6	14	5,468	e.	34	nw.	29	9	0	22	7.2	6.0	....
Brownsville	57	3	40	.....	.....	.....	54.2	.....	76	1	60	36	15	48	23	.....	.....	.....	2.19	.....	13	.....	n.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	30.10	30.12	.00	50.8	− 5.8	76	1	55	32	14	46	18	48	45	85	1.55	+ 0.2	13	8,264	n.	36	s.	1	1	6	24	8.5	T.	....
Dallas	512	109	117	29.62	30.19	.....	40.0	.....	60	1	45	17	14	35	23	.....	.....	.....	3.43	.....	13	6,029	nw.	32	nw.	13	8	6	17	6.7	T.	....
Fort Worth	670	106	114	29.43	30.17	+ .05	39.7	− 7.8	61	1	46	18	15	34	25	37	33	80	4.40	+ 3.2	13	6,332	nw.	32	nw.	29	6	5	20	7.3	T.	....
Galveston	54	106	114	30.07	30.13	+ .01	50.2	− 6.1	68	1	55	28	14	46	19	47	44	82	4.43	+ 0.7	16	9,903	n.	33	se.	2	5	7	19	7.3	.....	.....
Houston	138	111	121	29.97	30.12	.....	48.6	− 5.9	71	24	55	26	14	42	24	.....	.....	.....	11.43	.....	17	6,087	ne.	36	se.	2	5	6	20	7.7	.....	.....
Palestine	510	64	72	29.60	30.14	+ .02	42.4	− 7.0	61	2	48	19	14	37	27	39	37	85	6.19	+ 2.5	16	4,533	ne.	24	nw.	29	7	4	20	7.3	T.	....
San Antonio	701	109	132	29.40	30.14	+ .03	46.3	− 6.8	72	1	53	26	15	40	25	42	39	79	1.43	− 0.1	12	5,729	ne.	32	ne.	25	8	7	16	7.0	.....	.....
Taylor	582	55	63	29.54	30.17	+ .06	42.7	− 7.9	73	1	48	20	14	37	24	.....	.....	.....	3.08	+ 0.5	12	5,634	n.	25	nw.	2	7	6	18	7.2	T.	....

TABLE I.—*Climatological data for United States Weather Bureau stations, December, 1914*—Continued.

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.							31.4	− 5.4												82	4.72	+ 1.3									7.8		
Chattanooga	762	189	213	29.34	30.18	+ .02	38.4	− 4.2	62	1	44	6	15	33	20	35	31	76	8.17	+ 3.8	16	5,330	ne.	30	sw.	29	3	4	24	8.3	5.2	....
Knoxville	996	93	100	29.07	30.16	+ .00	36.8	− 2.9	64	1	43	5	15	31	24	34	32	82	7.86	+ 3.7	14	3,405	ne.	22	sw.	29	2	7	22	8.4	8.0	....
Memphis	399	76	97	29.78	30.22	+ .07	36.2	− 7.3	65	2	42	11	15	31	19	34	30	80	6.35	+ 2.0	17	5,385	n.	36	nw.	29	7	4	20	7.2	8.7	....
Nashville	546	168	191	29.59	30.19	+ .04	35.8	− 5.3	63	1	42	4	15	29	25	33	31	84	5.06	+ 1.2	12	6,130	ne.	34	w.	21	4	3	24	8.0	4.2	....
Lexington	989	75	102	29.06	30.17	+ .03	30.4	− 6.0	62	1	36	− 7	15	24	23	....	....	....	4.40	+ 1.1	16	7,135	w.	34	w.	13	3	6	22	8.0	10.7	....
Louisville	525	219	255	29.60	30.20	+ .06	31.1	− 7.0	62	2	37	0	15	25	25	30	28	86	4.06	+ 0.3	14	7,622	n.	38	ne.	25	3	7	21	8.0	5.7	T.
Evansville	431	72	82	29.71	30.20	+ .07	31.0	− 5.4	64	2	36	3	15	26	24	29	26	79	3.62	− 0.2	16	4,850	ne.	21	ne.	25	5	5	21	7.7	4.7	....
Indianapolis	822	154	164	29.27	30.19	+ .05	25.8	− 6.8	62	1	32	− 7	15	19	23	24	22	84	3.37	+ 0.3	16	5,058	ne.	30	sw.	29	6	2	23	7.7	11.1	1.7
Terre Haute	575	96	129	29.55	30.20	.....	25.8	.....	62	1	33	− 5	26	19	25	24	22	86	2.29	.....	15	6,774	nw.	29	w.	29	2	11	18	7.7	8.5	0.5
Cincinnati	628	152	160	29.48	30.19	+ .06	30.2	− 6.2	62	1	36	− 3	15	24	26	29	26	82	3.14	+ 0.2	14	5,582	w.	30	sw.	29	7	3	21	7.6	4.4	....
Columbus	824	173	222	29.27	30.18	+ .06	27.6	− 5.2	59	1	34	− 4	15	22	26	25	22	80	2.91	+ 0.2	17	8,721	w.	44	sw.	30	6	1	24	7.7	6.0	T.
Dayton	899	181	216	29.16	30.16	.....	26.6	− 6.5	62	1	33	− 5	15	20	23	25	23	85	2.86	+ 0.2	16	7,709	ne.	39	w.	30	8	6	17	6.9	5.6	T.
Pittsburgh	842	353	410	29.24	30.18	+ .07	29.9	− 4.8	62	2	36	− 2	15	24	27	27	23	77	4.37	+ 1.6	19	8,808	w.	46	w.	30	5	3	23	7.9	15.7	0.1
Elkins	1,940	41	50	28.04	30.20	+ .06	28.7	− 3.8	59	2	37	−10	16	21	39	28	24	86	5.16	+ 1.7	20	3,081	w.	24	sw.	30	4	6	21	8.0	9.4	T.
Parkersburg	638	77	84	29.51	30.19	+ .05	30.6	− 4.6	64	1	37	− 5	16	24	32	28	26	83	4.75	+ 2.0	18	4,104	sw.	24	nw.	30	4	3	24	8.0	7.1	....
Lower Lake Region.							24.9	− 4.3												80	3.01	+ 0.1									7.9		
Buffalo	767	247	280	29.28	30.15	+ .09	26.0	− 4.1	59	1	31	2	26	21	26	24	22	84	3.49	+ 0.1	16	15,488	w.	78	sw.	21	2	6	23	8.6	28.2	4.0
Canton	448	10	61	29.64	30.14	.....	20.6	− 2.1	58	2	28	−29	26	13	34	.....	.....	.....	2.15	− 1.4	11	10,065	sw.	53	w.	21	7	4	20	7.3	20.1	4.5
Oswego	335	76	91	29.77	30.15	+ .09	25.4	− 3.8	59	2	31	− 9	26	20	35	24	21	82	4.34	+ 0.8	15	9,469	s.	42	w.	21	2	5	24	8.4	41.7	10.5
Rochester	523	97	113	29.57	30.17	+ .11	26.4	− 2.5	60	1	32	− 1	26	21	24	24	20	75	2.31	− 0.6	14	7,910	sw.	42	w.	21	7	2	22	7.8	16.1	3.0
Syracuse	597	97	113	29.50	30.17	+ .10	25.4	− 2.9	64	2	31	−12	26	19	31	23	18	75	3.16	+ 0.5	14	9,163	s.	48	s.	21	5	5	21	7.3	15.8	3.0
Erie	714	92	102	29.35	30.15	+ .08	27.6	− 4.1	62	1	33	0	26	22	29	25	21	77	3.42	+ 0.4	23	9,444	sw.	36	s.	21	1	4	26	8.7	18.2	0.9
Cleveland	762	190	201	29.32	30.17	+ .08	27.0	− 4.1	55	1	32	− 1	15	22	31	25	20	77	1.57	− 1.0	18	10,160	sw.	42	w.	21	0	11	20	8.3	6.9	0.1
Sandusky	623	62	103	29.47	30.18	+ .09	25.4	− 6.7	55	1	31	− 4	15	20	27	24	21	83	3.08	+ 0.7	17	10,751	sw.	37	sw.	14	4	5	22	7.5	12.8	2.5
Toledo	628	208	246	29.48	30.19	+ .11	24.1	− 6.4	56	1	30	− 5	15	18	26	23	20	84	4.18	+ 1.9	15	12,261	sw.	41	sw.	14	8	2	21	7.1	18.5	5.7
Fort Wayne	856	113	124	29.22	30.19	.....	22.6	− 4.7	57	1	29	−10	15	16	27	22	19	85	3.58	.....	15	7,720	sw.	33	sw.	29	6	3	22	7.6	22.0	4.8
Detroit	730	218	245	29.34	30.17	+ .10	23.8	− 5.7	57	1	30	− 1	15	18	24	22	20	83	2.42	0.0	15	10,731	sw.	39	w.	21	2	8	21	8.2	15.1	5.0
Upper Lake Region.							19.8	− 4.7												81	1.43	− 0.7									7.5		
Alpena	609	13	92	29.45	30.15	+ .13	21.8	− 3.0	48	1	28	− 3	25	16	22	20	17	82	0.86	− 1.4	9	9,762	w.	36	nw.	22	2	12	17	7.4	15.2	7.1
Escanaba	612	54	60	29.47	30.17	+ .14	16.8	− 4.8	45	1	23	− 7	23	11	20	15	11	75	0.38	− 1.3	8	7,903	nw.	37	ne.	8	9	10	12	5.7	4.0	2.5
Grand Haven	632	54	92	29.46	30.17	+ .12	25.3	− 4.8	54	1	30	7	14	21	23	23	20	81	2.05	− 0.5	20	10,296	w.	43	sw.	21	2	3	26	8.8	18.2	12.0
Grand Rapids	707	70	87	29.37	30.18	+ .13	24.6	− 4.2	56	1	29	7	17	20	23	23	20	82	1.89	− 0.6	19	5,694	ne.	24	w.	21	1	3	27	9.2	17.6	7.0
Houghton	684	62	72	29.40	30.16	+ .14	17.2	− 3.7	48	1	22	− 5	31	12	20	.....	.....	.....	2.35	− 0.1	15	7,803	w.	36	w.	21	1	6	24	8.6	24.0	15.7
Lansing	878	11	62	29.18	30.16	.....	21.6	− 5.2	59	1	28	−15	26	15	31	20	18	87	1.57	− 0.5	20	5,319	sw.	20	sw.	21	3	7	21	8.0	14.4	7.1
Ludington	637	60	66	29.44	30.16	.....	24.6	.....	54	1	30	4	14	20	21	23	20	81	1.77	.....	20	9,651	w.	38	w.	21	1	2	28	9.2	18.0	10.0
Marquette	734	77	111	29.33	30.18	+ .16	18.4	− 4.5	50	1	24	− 5	23	13	23	16	11	75	0.85	− 1.7	9	9,406	sw.	42	sw.	18	2	7	22	8.0	9.2	4.4
Port Huron	638	70	120	29.44	30.16	+ .10	22.8	− 4.5	54	1	29	− 7	26	17	28	21	18	83	1.35	− 0.8	13	9,203	sw.	32	w.	14	3	14	14	7.2	13.4	8.8
Saginaw	641	48	82	29.44	30.17	.....	22.0	.....	57	1	28	−12	26	16	27	21	19	90	1.36	− 0.6	15	7,955	ne.	30	ne.	8	3	8	20	7.9	11.6	10.4
Sault Ste. Marie	614	11	61	29.41	30.15	+ .15	18.8	− 1.7	44	1	25	− 9	25	12	22	17	13	80	2.16	− 0.2	19	7,171	sw.	46	nw.	22	2	12	17	7.5	21.5	14.8
Chicago	823	140	310	29.27	30.20	+ .12	24.1	− 5.2	58	1	30	− 4	26	18	24	22	17	71	2.33	+ 0.3	15	10,253	w.	36	ne.	5	6	7	18	6.8	8.4	3.7
Green Bay	617	109	144	29.49	30.19	+ .15	16.3	− 5.0	50	1	22	−18	26	10	29	14	10	75	0.99	− 0.8	13	9,610	sw.	42	n.	8	8	5	18	6.9	11.4	7.2
Milwaukee	681	119	133	29.42	30.19	+ .13	20.4	− 5.6	54	1	27	− 8	26	14	26	19	16	83	1.55	− 0.4	14	8,953	w.	35	e.	5	10	5	16	6.1	8.9	4.0
Duluth	1,133	11	47	28.92	30.22	+ .17	9.4	− 8.3	40	1	17	−20	25	2	26	8	6	89	0.30	− 0.9	6	10,481	sw.	53	nw.	29	11	6	14	5.4	5.4	1.8
North Dakota.							6.4	− 5.5												84	0.34	− 0.3									5.9		
Moorhead	940	8	57	29.19	30.27	+ .19	7.7	− 3.0	42	4	17	−27	25	−2	32	5	2	83	0.34	− 0.4	8	6,293	nw.	30	nw.	13	17	6	8	4.0	3.4	2.5
Bismarck	1,674	8	57	28.38	30.28	+ .20	7.4	− 7.6	44	2	18	−30	25	−3	54	6	3	85	0.34	− 0.3	7	6,202	nw.	40	w.	31	7	11	13	6.1	4.7	4.0
Devils Lake	1,482	11	44	28.53	30.21	+ .15	3.6	− 4.4	32	31	13	−27	25	−6	35	2	0	88	0.36	0.0	6	7,308	w.	34	n.	13	9	5	17	6.1	4.8	3.0
Williston	1,872	40	47	28.11	30.21	+ .15	6.7	− 6.9	40	3	16	−30	25	−3	38	6	3	81	0.33	− 0.3	8	3,994	n.	48	nw.	31	5	6	20	7.1	3.1	2.5
Upper Mississippi Valley.							20.5	− 6.9												84	1.60	− 0.2									7.0		
Minneapolis	918	10	208	29.17	30.20	.....	12.2	.....	44	1	19	−20	26	6	32	.....	.....	.....	0.37	− 0.6	9	8,254	w.	33	nw.	29	9	6	16	6.3	8.4	3.4
St. Paul	837	201	236	29.30	30.26	+ .18	12.1	− 7.2	48	1	19	−22	26	5	32	.....	.....	.....	0.50	− 0.6	8	8,417	nw.	36	nw.	21	8	5	18	6.8	7.0	4.0
La Crosse	714	11	48	29.43	30.25	+ .17	15.2	− 7.6	49	1	22	−24	26	8	35	.....	.....	.....	0.99	− 0.3	11	4,157	w.	20	sw.	22	7	10	14	6.7	10.8	4.5
Madison	974	70	78	29.11	30.23	+ .15	16.4	− 6.3	51	1	23	−16	26	10	28	15	12	82	1.76	0.0	8	8,272	nw.	36	ne.	8	7	8	16	6.6	10.8	8.8
Charles City	1,015	10	49	29.10	30.25	+ .15	12.8	− 6.2	41	5	21	−24	26	5	37	12	10	90	0.94	− 0.3	9	4,670	nw.	24	nw.	29	8	8	15	6.6	10.2	4.6
Davenport	606	71	79	29.53	30.24	+ .14	19.8	− 7.4	53	1	27	−15	26	12	32	19	17	88	1.67	0.0	11	5,808	nw.	24	nw.	29	6	9	16	6.7	10.5	5.0
Des Moines	861	84	97	29.28	30.23	+ .12	18.7	− 7.0	51	1	26	−15	26	11	35	17	14	82	1.28	0.0	9	5,249	nw.	26	nw.	29	6	6	19	7.2	10.7	4.2
Dubuque	698	81	96	29.46	30.25	+ .15	18.4	− 6.1	52	1	25	−20	26	11	34	16	13	83	1.83	+ 0.1	8	4,944	nw.	20	nw.	13	7	8	16	6.7	14.6	8.4
Keokuk	614	64	78	29.52	30.23	+ .11	22.6	− 6.8	55	1	30	−12	26	15	33	21	18	83	1.55	− 0.3	13	5,797	n.	30	nw.	29	6	8	17	6.5	13.0	5.0
Cairo	356	87	93	29.79	30.19	+ .04	32.4	− 6.1	60	2	38	4	15	27	22	30	28	83	3.51	+ 0.2	14	6,232	nw.	33	n.	25	7	1	23	7.7	6.3	....
Peoria	609	11	45	29.53	30.22	+ .11	20.8	− 7.3	57	1	29	−19	26	13	33	20	18	89	1.81	− 0.6	12	5,769	s.	24	nw.	29	5	6	20	7.6	14.4	4.5
Springfield, Ill.	644	10	91	29.49	30.21	+ .09	24.2	− 7.1	59	1	31	− 7	26	18	24	23	20	84	2.20	− 0.2	18	6,501	nw.	27	w.	29	5	7	19	7.6	8.6	0.9
Hannibal	534	74	109	29.62	30.23	+ .11	23.9	− 7.4	58	1	31	− 8	26	17	30	.....	.....	.....	1.72	+ 0.1	14	6,122	nw.	26	nw.	29	7	5	19	7.3	10.6	2.0
St. Louis	567	265	303	29.57	30.20	+ .07	28.6	− 6.9	60	1	34	2	26	23	21	27	23	80	2.23	+ 0.1	17	8,619	nw.	37	nw.	29	4	7	20	7.7	2.4	....
Missouri Valley.							19.6	− 7.3												83	1.16	+ 0.1									6.6		
Columbia, Mo.	781	11	84	29.34	30.22	+ .10	25.4	− 7.5	55	1	32	− 6	26	19	31	.....	.....	.....	1.86	− 0.2	12	5,713	n.	30	w.	29	4	5	22	7.9	5.8	1.2
Kansas City	963	161	181	29.15	30.23	+ .11	24.2	− 7.3	54	1	31	− 4	14	18	30	22	17	74	1.52	+ 0.2	12	8,049	n.	36	nw.	29	6	6	19	6.9	11.8	2.0
St. Joseph	967	11	49	29.16	30.24	.....	21.6	.....	52	1	29	− 8	14	14	28	20	17	83	1.08	.....	12	5,286	nw.	31	nw.	29	7	6	18	6.9	11.2	2.7
Springfield, Mo	1,324	98	104	28.74	30.20	+ .07	27.4	− 8.1	56	1	33	− 2	14	22	24	26	24	86	2.90	+ 0.2	16	7,182	nw.	28	w.	29	5	5	21	7.7	2.3	....
Iola	984	11	50	29.13	30.24	+ .12	26.2	− 6.3	57	1	33	− 1	14	19	29	.....	.....	.....	0.82	− 0.1	9	5,148	n.	27	ne.	24	3	9	19	7.6	3.9	T.
Topeka	983	85	101	.....	.....	.....	22.8	− 8.3	51	1	30	− 5	26	16	33	.....	.....	.....	1.08	+ 0.2	9	5,707	n.	33	nw.	29	7	6	18	6.9	15.6	1.9
Lincoln	1,189	11	84	28.92	30.26	+ .14	18.1	− 8.8	50	1	26	− 9	14	10	33	16	14	87	0.91	+ 0.2	11	6,029	n.	37	nw.	29	10	6	15	6.1	7.2	4.0
Omaha	1,105	115	121	29.01	30.26	+ .15	18.2	− 8.9	46	1	25	− 7	16	11	28	17	14	85	1.38	+ 0.5	12	5,700	nw.	31	nw.	29	11	5	15	6.4	10.5	4.5
Valentine	2,598	47	54	27.37	30.23	+ .13	15.8	− 8.7	52	3	27	−23	16	4	37	14	10	85	0.68	+ 0.1	7	6,550	nw.	33	s.	26	10	12	9	5.6	6.9	1.5
Sioux City	1,135	94	164	28.97	30.26	+ .14	15.0	− 7.6	46	1	24	−14	14	6	32	14	12	87	1.44	+ 0.7	11	7,454	nw.	40	nw.	29	9	8	14	6.1	12.7	3.4
Huron	1,306	59	74	28.79	30.28	+ .16	11.6	− 4.1	49	3	22	−20	16	1	35	10	6	80	0.30	− 0.3	8	7,622	se.	32	se.	26	11	12	8	5.2	7.2	1.2
Pierre	1,572	70	75	28.51	30.28	+ .18	15.1	− 5.0	58	3	26	−20	16	5	41	12	8	79	0.22	− 0.3	6	6,555	se.	40	nw.	26	9	10	12	5.7	3.0	T.
Yankton	1,233	49	57	28.87	30.27	+ .16	15.1	− 7.1	51	4	25	−16	16	5	33	.....	.....	.....	0.76	0.0	7	5,070	w.	26	nw.	29	8	8	15	6.6	7.6	1.5

TABLE I.—*Climatological data for United States Weather Bureau stations, December, 1914*—Continued.

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.						
Northern Slope.							**17.2**	**— 6.5**											**86**	**0.41**	**— 0.5**									**5.7**		
Havre	2,505	11	44	27.42	30.20	+ .15	10.8	—10.4	43	3	20	—25	16	2	41		11	9	91	0.66	0.0	9	4,765	w.	32	sw.	31	6	9	16	6.8	6.7	6.4
Helena	4,110	87	114	25.81	30.19	+ .06	20.0	— 4.8	45	31	27	— 6	16	13	22		17	14	79	0.25	— 0.6	7	4,104	sw.	30	w.	22	6	9	16	6.6	4.3	0.1
Kalispell	2,962	11	34	27.00	30.20	+ .13	19.0	— 4.9	44	3	26	— 4	18	12	22		17	14	83	0.40	— 1.4	8	2,322	nw.	11	nw.	20	8	10	13	6.1	4.0	1.8
Miles City	2,371	26	48	27.57	30.26	+ .16	15.2	— 5.8	47	2	24	—20	16	6	36		13	9	79	0.49	— 0.1	8	3,041	w.	18	ne.	26	12	10	9	5.0	4.5	T.
Rapid City	3,259	50	58	26.64	30.25	+ .16	19.8	— 6.2	54	2	30	—11	16	10	36		16	11	73	0.46	0.0	5	5,013	n.	36	n.	31	9	11	11	5.8	4.2	0.3
Cheyenne	6,088	84	101	23.94	30.18	+ .09	20.2	— 8.8	45	4	30	— 6	16	10	33		17	12	74	0.16	— 0.2	4	7,883	w.	56	w.	31	13	10	8	5.1	1.8	T.
Lander	5,372	60	68	24.62	30.24	+ .09	15.2	— 4.0	49	31	28	—15	17	2	39		10	3	63	0.31	— 0.4	5	1,956	sw.	19	se.	23	7	18	6	5.4	3.5	T.
Sheridan	3,790	10	47	26.13	30.24	.....	14.2	.....		48	31	28	—21	17	0		42	10	7	81	0.14	.....	5	2,655	s.	24	n.	14	9	12	10	4.8	2.3	T.
Yellowstone Park	6,200	11	48	23.82	30.21	+ .05	17.0	— 4.6	38	4	26	—10	16	8	31		13	8	71	0.07	— 1.8	6	4,610	s.	25	sw.	21	11	4	16	6.1	0.7	0.2
North Platte	2,821	11	51	27.18	30.28	+ .18	18.0	— 8.6	52	3	28	—11	16	7	34		14	10	80	0.87	+ 0.4	11	4,384	nw.	24	n.	20	15	5	11	4.9	7.4	1.9
Middle Slope.							**24.9**	**— 8.1**											**78**	**0.95**	**+ 0.2**									**5.9**		
Denver	5,291	129	172	24.70	30.16	+ .08	24.4	— 7.8	54	31	35	— 7	21	13	42		20	14	70	0.72	+ 0.1	5	4,390	sw.	28	nw.	28	15	8	8	4.5	9.7	0.3
Pueblo	4,685	80	86	25.28	30.15	+ .07	24.6	— 7.1	55	31	38	—16	21	11	45		19	13	66	0.59	+ 0.1	8	3,150	nw.	25	w.	11	18	7	6	3.9	8.2	.....
Concordia	1,398	42	50	28.71	30.26	+ .15	19.9	— 9.6	52	3	29	— 8	16	11	38		18	16	86	0.57	+ 0.1	10	3,546	n.	23	nw.	29	5	6	20	7.5	5.4	1.9
Dodge	2,509	11	51	27.48	30.21	+ .11	23.4	— 8.2	54	4	33	— 6	21	14	39		20	15	76	0.46	— 0.1	6	6,029	nw.	30	ne.	15	11	8	12	5.5	6.4	T.
Wichita	1,358	139	158	28.71	30.21	+ .10	25.7	— 8.5	53	4	33	2	14	18	31		24	21	84	0.61	— 0.2	8	7,874	n.	44	nw.	29	6	8	17	7.0	3.3	T.
Oklahoma	1,214	10	47	28.88	30.21	+ .10	31.4	— 7.2	52	1	38	5	26	25	27		29	26	84	2.74	+ 1.0	12	9,553	n.	46	nw.	29	7	7	17	7.0	9.0	.....
Southern Slope.							**37.0**	**— 6.8**											**80**	**1.25**	**+ 0.4**									**6.2**		
Abilene	1,738	10	52	28.31	30.17	+ .06	38.7	— 6.3	60	5	47	16	14	31	30		35	31	81	1.61	+ 0.5	9	5,698	n.	23	sw.	26	9	3	19	6.6	T.	.....
Amarillo	3,676	10	49	26.30	30.15	+ .06	30.4	— 6.0	62	18	40	10	21	21	36		27	24	82	1.17	+ 0.3	6	7,450	sw.	35	e.	24	13	11	7	4.7	11.6	.....
Del Rio	944	64	71	29.10	30.11	+ .01	45.6	— 6.8	73	1	52	25	15	39	29		.....	.....	.....	0.45	— 0.4	7	5,651	se.	30	nw.	25	6	6	19	7.0	T.	.....
Roswell	3,566	75	85	26.41	30.12	+ .05	33.1	— 8.1	64	18	42	12	14	24	35		30	26	77	1.78	+ 1.2	11	4,288	s.	36	ne.	24	8	8	15	6.7	7.1	.....
Southern Plateau.							**37.1**	**— 5.0**											**76**	**2.10**	**+ 1.5**									**4.7**		
El Paso	3,762	110	133	26.18	30.01	— .02	42.8	— 2.0	62	18	51	22	15	34	27		38	32	70	3.94	+ 3.4	10	7,338	se.	46	nw.	28	14	9	8	4.7	T.	.....
Santa Fe	7,013	57	62	23.18	30.10	— .04	26.0	— 4.3	46	23	34	6	15	18	27		22	19	78	1.70	+ 0.9	7	4,253	ne.	22	n.	30	6	15	10	5.9	13.9	2.0
Flagstaff	6,908	8	57	.....	.....	.....	23.6	— 4.8	48	3	36	—13	15	11	47		22	.....	.....	1.88	.....	9	.....	e.	30	e.	21	9	14	8	.....	20.7	4.5
Phoenix	1,108	76	81	28.81	29.98	— .06	50.3	— 1.6	68	30	59	28	15	41	32		45	40	72	3.09	+ 2.5	11	3,206	e.	29	e.	22	9	5	17	6.2	.....	.....
Yuma	141	9	58	29.84	30.00	— .05	51.0	— 4.7	68	31	61	33	15	40	31		44	37	66	0.98	+ 0.5	4	3,750	n.	30	n.	21	22	3	6	2.9	.....	.....
Independence	3,910	11	42	25.95	30.03	— .09	29.0	—12.6	50	4	40	3	20	17	30		27	26	92	0.78	0.0	3	3,887	nw.	32	nw.	22	18	6	7	3.8	9.5	.....
Middle Plateau.							**24.4**	**— 6.9**											**75**	**0.50**	**— 0.5**									**5.6**		
Reno	4,532	74	81	25.43	30.11	— .04	26.8	— 6.9	50	1	37	4	21	17	30		24	20	78	0.70	— 1.0	11	2,668	w.	32	se.	2	8	9	14	6.2	9.2	0.2
Tonopah	6,090	12	20	23.99	30.11	.....	24.8	.....	42	25	30	6	20	20	16		22	17	70	0.52	— 0.3	2	5,985	se.	33	se.	2	14	6	11	4.9	5.5	.....
Winnemucca	4,344	18	56	25.62	30.17	— .01	18.9	—11.8	48	1	32	—10	14	5	39		17	13	79	0.57	— 0.4	8	3,543	ne.	20	ne.	17	9	6	16	6.2	7.8	1.0
Modena	5,479	10	43	24.57	30.10	— .02	21.2	—10.5	46	2	34	— 6	15	8	38		18	14	75	0.46	— 0.1	5	5,444	w.	31	sw.	28	7	12	12	5.8	5.0	0.6
Salt Lake City	4,360	147	189	25.64	30.12	— .03	29.0	— 3.1	52	4	36	12	22	22	20		25	20	70	0.39	— 0.9	6	3,793	se.	25	se.	3	13	11	7	4.9	4.6	1.2
Durango	6,546	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Grand Junction	4,602	82	96	25.41	30.09	— .01	26.2	— 2.0	49	3	35	6	15	17	28		22	18	76	0.26	— 0.2	5	3,475	e.	24	se.	22	11	9	11	5.3	4.2	T.
Northern Plateau.							**23.8**	**— 8.2**											**78**	**0.65**	**— 1.1**									**6.4**		
Baker	3,471	48	53	26.50	30.21	— .05	20.8	— 6.6	39	3	30	— 4	16	11	28		18	13	73	0.56	— 1.0	7	4,676	se.	19	se.	3	11	13	7	4.6	4.9	0.7
Boise	2,739	78	86	27.27	30.24	+ .04	24.0	— 8.2	51	3	32	3	17	16	23		21	17	74	0.47	— 1.2	5	2,586	nw.	22	se.	5	7	9	15	6.0	2.7	.....
Lewiston	757	40	48	29.35	30.20	+ .07	28.4	— 9.1	52	2	36	8	21	21	29		.....	.....	.....	0.32	— 1.2	5	1,951	e.	16	ne.	30	8	9	14	6.6	0.9	.....
Pocatello	4,477	46	54	25.50	30.21	+ .02	19.5	— 8.9	48	3	29	— 7	22	10	28		17	14	81	0.56	— 0.3	10	3,518	se.	24	sw.	28	7	13	11	5.8	6.9	3.5
Spokane	1,929	101	110	28.06	30.19	+ .11	24.4	— 6.4	45	1	30	1	17	18	20		22	19	78	1.46	— 1.2	12	2,681	ne.	21	sw.	3	5	12	14	6.7	11.5	6.6
Walla Walla	1,000	57	65	29.06	30.18	+ .06	26.0	—10.0	55	1	30	8	21	22	22		24	22	86	0.53	— 1.6	6	2,342	s.	26	se.	1	2	6	23	8.4	0.6	T.
North Pacific Coast Region.							**39.1**	**— 2.5**											**81**	**2.36**	**— 5.6**									**6.7**		
North Head	211	11	56	29.80	30.03	.00	42.0	— 2.3	54	31	46	30	16	38	14		40	37	85	4.62	— 2.9	14	10,042	e.	52	se.	31	10	5	16	6.3	T.	.....
Port Crescent	259	8	53	29.76	30.05	+ .07	37.4	— 0.9	48	9	43	23	13	32	17		.....	.....	.....	1.17	— 5.7	9	5,005	se.	28	ne.	19	2	11	18	7.5	0.2	.....
Seattle	125	215	250	29.94	30.08	+ .07	39.7	— 1.5	54	9	45	24	13	35	15		37	33	79	1.39	— 4.6	11	5,214	se.	35	se.	7	7	7	17	6.8	T.	.....
Tacoma	213	113	120	29.84	30.07	+ .06	37.8	— 2.5	51	9	44	22	18	32	18		35	31	77	1.62	— 5.7	9	2,998	s.	20	w.	28	6	8	17	6.7	T.	.....
Tatoosh Island	109	7	57	29.91	30.01	+ .05	42.9	— 1.0	50	31	46	36	14	40	9		41	38	83	3.61	—11.0	15	15,314	e.	57	e.	7	7	10	14	6.3	.....	.....
Portland, Oreg	153	68	106	29.90	30.07	.00	36.8	— 4.5	51	31	42	22	21	32	18		34	30	75	2.56	— 4.8	14	4,459	e.	30	e.	7	8	5	18	6.5	T.	.....
Roseburg	510	9	57	29.48	30.04	— .07	37.0	— 4.9	60	31	42	19	21	32	25		35	33	88	1.53	— 4.4	13	1,608	s.	13	se.	25	1	18	12	6.7	0.5	.....
Middle Pacific Coast Region.							**45.2**	**— 3.2**											**81**	**5.30**	**+ 0.9**									**6.0**		
Eureka	62	73	89	29.94	30.01	— .11	45.3	— 2.7	62	22	52	32	21	39	26		43	40	81	7.09	— 0.2	14	4,524	se.	25	s.	0	8	8	15	6.6	.....	.....
Mount Tamalpais	2,375	11	18	27.50	30.00	— .12	40.6	— 7.0	57	22	44	29	16	37	14		38	34	82	5.79	+ 1.9	14	12,269	ne.	58	n.	21	7	7	17	6.8	6.0	.....
Point Reyes Light	490	7	18	29.44	29.96	.....	49.4	— 1.2	68	22	54	37	17	45	18		.....	.....	.....	4.30	.....	15	11,147	s.	64	s.	9	8	11	12	5.5	.....	.....
Red Bluff	332	50	56	29.68	30.05	— .09	42.2	— 4.2	67	23	49	28	26	35	30		39	35	80	6.23	+ 1.7	15	3,908	nw.	24	n.	20	10	5	16	6.0	.....	.....
Sacramento	69	106	117	29.96	30.04	— .10	43.8	— 2.5	65	22	50	30	8	37	31		42	39	84	3.44	— 0.1	15	5,110	se.	27	se.	1	11	8	12	5.2	.....	.....
San Francisco	155	209	213	29.85	30.02	— .10	48.7	— 2.2	67	22	53	41	15	44	19		45	41	79	5.49	+ 1.2	15	4,934	ne.	31	se.	9	6	8	17	6.4	.....	.....
San Jose	141	12	110	29.87	30.02	.....	46.2	— 2.3	65	22	55	29	14	38	29		.....	.....	.....	3.73	+ 0.7	14	4,397	se.	35	e.	16	11	9	11	5.2	.....	.....
South Pacific Coast Region.							**50.8**	**— 2.2**											**76**	**3.43**	**+ 1.3**									**5.8**		
Fresno	327	89	98	29.68	30.05	— .08	44.7	— 2.1	60	9	52	27	22	37	27		42	38	80	1.76	+ 0.2	8	3,587	e.	26	s.	1	6	14	11	6.2	.....	.....
Los Angeles	338	159	191	29.63	30.00	— .07	53.4	— 3.1	74	30	61	40	14	46	25		48	44	74	3.73	+ 0.8	10	4,590	ne.	31	ne.	16	10	9	12	5.7	.....	.....
San Diego	87	62	70	29.89	29.99	— .08	54.6	— 1.1	70	31	62	39	14	47	22		49	44	72	2.21	+ 0.4	16	3,950	e.	33	s.	1	15	6	10	4.8	.....	.....
San Luis Obispo	201	32	40	29.82	30.04	— .07	50.3	— 2.5	68	23	60	33	14	41	31		46	42	78	6.01	+ 3.7	15	2,411	n.	22	ne.	21	7	10	14	6.3	.....	.....
West Indies.																																
San Juan	82	8	54	29.91	30.00	+ .03	78.0	.....	86	9	84	70	19	72	14		.....	.....	.....	1.66	— 4.5	19	8,017	se.	37	e.	30	17	13	1	3.6	.....	.....
Panama.																																
Balboa Heights	118	7	97	29.70	29.82	.....	81.2	.....	92	5	88	72	28	74	17		76	75	92	8.28	+ 3.8	20	4,669	nw.	36	se.	26	3	15	13	6.4	.....	.....
Colon	25	5	71	29.80	29.82	.....	81.5	.....	89	11	85	75	13	78	11		78	77	89	8.88	— 3.2	20	8,187	ne.	29	ne.	10	6	17	8	5.9	.....	.....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1914, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	24			0.76														0.16			
Albany, N. Y.	13–14			0.67														(*)			
Alpena, Mich.	29–30			0.36														(*)			
Amarillo, Tex.	24–25			0.73														(*)			
Anniston, Ala.	24–25			1.40														(*)			
Asheville, N. C.	4			1.30														.35			
Atlanta, Ga.	3–4	8.55 a. m.[1]	7.55 a. m.[2]	2.41	11.07 p. m.[1]	11.31 p. m.[1]	0.48	0.13	0.36	0.43	0.46	0.54									
Atlantic City, N. J.	21			1.26														.38			
Augusta, Ga.	1			0.56														.25			
Baker, Oreg.	28			0.17														(*)			
Baltimore, Md.	29			0.49														.24			
Bentonville, Ark.	1			0.93														.42			
Binghamton, N. Y.	13			0.64														.12			
Birmingham, Ala.	25			1.59														.50			
Bismarck, N. Dak.	7			0.09														(*)			
Block Island, R. I.	7			1.18														(*)			
Boise, Idaho.	3–4			0.20														(*)			
Boston, Mass.	29			0.39														.25			
Buffalo, N. Y.	16–17			1.03														(*)			
Burlington, Vt.	13–14			0.50														(*)			
Cairo, Ill.	19			0.67														.20			
Canton, N. Y.	13–14			0.89														(*)			
Charles City, Iowa.	7–8			0.38														(*)			
Charleston, S. C.	19			0.50														.25			
Charlotte, N. C.	4			1.09														.30			
Chattanooga, Tenn.	3			2.13														.67			
Cheyenne, Wyo.	6–7			0.08														(*)			
Chicago, Ill.	29			0.70														(*)			
Cincinnati, Ohio.	4			0.71														.23			
Cleveland, Ohio.	7–8			0.51														(*)			
Columbia, Mo.	28–29			0.63														(*)			
Columbia, S. C.	29			0.59														.30			
Columbus, Ohio.	3–4			0.69														(*)			
Concord, N. H.	13–14			1.15														(*)			
Concordia, Kans.	20			0.38														(*)			
Corpus Christi, Tex.	2			0.34																	
Davenport, Iowa.	28–29			0.84														(*)			
Dayton, Ohio.	4			1.19														0.17			
Del Rio, Tex.	24			0.30														.18			
Denver, Colo.	7–8			0.44														(*)			
Des Moines, Iowa.	20			0.41														(*)			
Detroit Mich.	29			0.53														(*)			
Devils Lake, N. Dak.	1			0.22														(*)			
Dodge City, Kans.	20			0.25														(*)			
Dubuque, Iowa.	28–29			0.86														(*)			
Duluth, Minn.	26			0.17														(*)			
Durango, Colo.																					
Eastport, Me.	19			0.38														.12			
Elkins, W. Va.	3			0.17														.15			
El Paso, Tex.	24			1.48														.48			
Erie, Pa.	14–15			0.71														(*)			
Escanaba, Mich.	20–21			0.12														(*)			
Eureka, Cal.	5			0.58														.33			
Evansville, Ind.	29			0.50														.18			
Flagstaff, Ariz.	17–18			0.69														(*)			
Fort Smith, Ark.	2			0.54														.21			
Fort Wayne, Ind.	29			0.64														.16			
Fort Worth, Tex.	1–2	4.12 a. m.[3]	3.15 a. m.[4]	2.25	7.30 a. m.[3]	7.42 a. m.[3]	0.27	0.25	0.53	0.61											
Fresno, Cal.	10			0.61														.19			
Galveston, Tex.	28			0.46														.39			
Grand Haven, Mich.	29			0.80														(*)			
Grand Junction, Colo.	7			0.10														(*)			
Grand Rapids, Mich.	29			0.55														(*)			
Green Bay, Wis.	29			0.39														(*)			
Hannibal, Mo.	28–29			0.55														(*)			
Harrisburg, Pa.	7			1.52														.21			
Hartford, Conn.	13–14			1.46														(*)			
Hatteras, N. C.	13	11.35 a. m.	7.35 p. m.	1.50	7.02 p. m.	7.14 p. m.	1.09	.07	.30	.41											
	28	11.07 a. m.	3.55 p. m.	0.71	3.25 p. m.	3.39 p. m.	0.34	.07	.30	.35											
Havre, Mont.	6–7			0.25														(*)			
Helena, Mont.	28			0.14														(*)			
Houghton, Mich.	14–15			0.82														(*)			
Houston, Tex.	1–2	4.20 p. m.[3]	5.45 a. m.[4]	7.40	6.18 p. m.[3]	7.46 p. m.	.11	.08	.27	.47	.77	1.12	1.33	1.62	1.90	2.08	2.25	2.54	3.21	3.42	
					8.46 p. m.	8.58 p. m.	3.69	.18	.36	.40											
					9.58 p. m.	11.06 p. m.	4.52	.08	.16	.30	.37	.43	.52	.59	.65	.70	.75	.93	1.14		
					4.23 a. m.[4]	4.44 a. m.	6.74	.10	.24	.44	.55	.59									
Do.	28	8.02 a. m.	7.20 p. m.	1.02	6.07 p. m.	6.43 p. m.	.27	.05	.28	.32	.44	.50	.53	.61	.65						
Huron, S. Dak.	7–8			0.14														(*)			
Independence, Cal.	16			0.44														(*)			
Indianapolis, Ind.	2			0.12														.11			
Iola, Kans.	20			0.44														(*)			
Jacksonville, Fla.	13			2.01														.67			
Kalispell, Mont.	26			0.19														(*)			
Kansas City, Mo.	11–12			0.41														(*)			
Keokuk, Iowa.	20			0.56														(*)			
Key West, Fla.	16			1.85														.65			
Knoxville, Tenn.	24–25			2.68														(*)			
La Crosse, Wis.	20			0.21														(*)			
Lander, Wyo.	7–8			0.25														(*)			
Lansing, Mich.	29			0.46														(*)			
Lewiston, Idaho.	28			0.17														.06			
Lexington, Ky.	19			0.83														.25			
Lincoln, Nebr.	20			0.44														(*)			
Little Rock, Ark.	12			1.59														.62			
Los Angeles, Cal.	1			0.76														.44			
Louisville, Ky.	29			0.61														.25			
Ludington, Mich.	29			0.54														(*)			
Lynchburg, Va.	29			0.51														.28			
Macon, Ga.	29			1.18														.45			

[1] Dec. 3. [2] Dec. 4. [3] Dec. 1. [4] Dec. 2. * Self-register not working.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1914, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Madison, Wis.	29			0.93																	
Marquette, Mich.	29–30			0.32														(*)			
Memphis, Tenn.	28			0.71														(*)			
Meridian, Miss.	24–25	7.30 p. m.	9.30 a. m.	0.99	2.19 a. m.	2.49 a. m.	.01	.05	.11	.21	.26	.46	.61					.37			
Miami, Fla.	13–14	11.01 p. m.	D. N. a. m.	0.84	1.30 a. m.	1.41 a. m.	.23	.18	.34	.39											
Milwaukee, Wis.	29			0.56																	
Minneapolis, Minn.	20–21			0.11														(*)			
Mobile, Ala.	28–29	5.20 p. m.	6.30 a. m.	2.12	3.45 a. m.	4.10 a. m.	.69	.30	.68	.99	1.16							(*)			
Modena, Utah	17			0.21																	
Montgomery, Ala.	3	5.28 p. m.	10.15 p. m.	1.64	6.04 p. m.	7.07 p. m.	.10	.10	.20	.36	.57	.82	.95	1.04	1.16	1.21	1.26	1.39	1.49		
	25	6.31 a. m.	11.50 a. m.	1.30	6.36 a. m.	7.12 a. m.	.01	.19	.38	.45	.48	.52	.57	.68	.72						
Moorhead, Minn.	20			0.08																	
Mount Tamalpais, Cal.	9			1.26														(*)			
Mount Weather, Va.	13			0.80														.40			
Nantucket, Mass.	19			0.44														(*)			
Nashville, Tenn.	3			0.91														.36			
New Haven, Conn.	13			1.76														.46			
New Orleans, La.	29			0.62														.42			
New York, N. Y.	21			0.96														.53			
Norfolk, Va.	28			0.42														0.24			
Northfield, Vt.	13–14			0.56														.14			
North Head, Wash.	7			0.64														(*)			
North Platte, Nebr.	19–20			0.38														.21			
Oklahoma, Okla.	24–25			1.67														(*)			
Omaha, Nebr.	20			0.60														(*)			
Oswego, N. Y.	13–14			1.54														(*)			
Palestine, Tex.	24			1.63														(*)			
Parkersburg, W. Va.	4			1.29														.55			
Pensacola, Fla.	12–13	7.02 p. m	5.05 a. m.	2.90	1.36 a. m.	3.14 a. m.	1.46	.09	.11	.17	.25	.35	.45	.58	.69	.80	.87	.98	1.14	1.33	
Peoria, Ill.	18–19			0.50														.17			
Philadelphia, Pa.	7–8			4.22														(*)			
Phoenix, Ariz.	21			0.30														(*)			
Pirrre, S. Dak.	7–8			0.17														.19			
Pittsburgh, Pa.	7–8			1.16														(*)			
Pocatello, Idaho	28			0.15														(*)			
Point Reyes Light, Cal.	6			0.26														(*)			
Port Huron, Mich.	29			0.32														.21			
Portland, Me.	21			1.51														(*)			
Portland, Oreg.	25			0.65														.26			
Providence, R. I.	13–14			0.90														.09			
Pueblo, Colo.	18–19			0.35														(*)			
Raleigh, N. C.	4			0.58														(*)			
Rapid City, S. Dak.	6–7			0.34														.30			
Reading, Pa.	29			0.62														(*)			
Red Bluff, Cal.	9			1.61														.34			
Reno, Nev.	9–10			0.21														.23			
Richmond, Va.	13			1.04														(*)			
Rochester, N. Y.	13–14			0.94														.28			
Roseburg, Oreg.	26			0.44														(*)			
Roswell, N. Mex.	24			0.72														.19			
Sacramento, Cal.	26			0.62														(*)			
Saginaw, Mich.	29–30			0.52														.20			
St. Joseph, Mo.	12			0.35														(*)			
St. Louis, Mo.	3–4			0.55														(*)			
St. Paul, Minn.	23			0.20														(*)			
Salt Lake City, Utah	11			0.18														(*)			
San Antonio, Tex.	1			0.24														(*)			
San Diego, Cal.	1			0.54														.11			
Sand Key, Fla.	16			1.28														0.37			
Sandusky, Ohio	8			0.75														.54			
San Francisco, Cal.	17			1.02														(*)			
San Jose, Cal.	16			0.62														.35			
San Luis Obispo, Cal.	1			0.94														.23			
Santa Fe, N. Mex.	19–20			0.72														.50			
Sault Ste. Marie, Mich.	14–15			0.59														(*)			
	19			0.43														(*)			
Savannah, Ga.	29			0.77														(*)			
Scranton, Pa.	7–8			2.47														.19			
Seattle, Wash.	30			0.29														(*)			
Sheridan, Wyo.	7			0.07														.23			
Shreveport, La.	2			1.32														(*)			
Sioux City, Iowa	20			0.56														.49			
Spokane, Wash.	27–28			0.45														(*)			
Springfield, Ill.	29			0.67														(*)			
Springfield, Mo.	1			0.88														(*)			
Syracuse, N. Y.	13–14			1.33														.34			
Tacoma, Wash.	30			0.29														(*)			
Tampa, Fla.	8	10.31 a. m.	1.27 p. m.	1.09	12.26 p. m.	1.09 p. m.	.12	.11	.19	.33	.35	.47	.69	.82	.87	.96		.16			
	25–26	10.03 p. m.	D. N. a. m.	1.00	10.13 p. m.	10.33 p. m.	.01	.17	.45	.68	.75										
Tatoosh Island, Wash.	29			0.51																	
Taylor, Tex.	1			0.76														.14			
Terre Haute, Ind.	3–4			0.57														.31			
Thomasville, Ga.	25	11.28 a. m.	4.20 p. m.	0.93	1.52 p. m.	2.15 p. m.	0.29	.05	.20	.34	.50	.53						(*)			
	29	6.55 a. m.	3.14 p. m.	2.00	10.34 a. m.	11.14 a. m.	0.95	.07	.11	.18	.29	.39	.49	.60	.75						
Toledo, Ohio	8–9			1.06																	
Tonopah, Nev.	16–17			0.52														(*)			
Topeka, Kans.	20			0.39														(*)			
Valentine Nebr.	7–8			0.38														(*)			
Vicksburg, Miss.	28			1.16														(*)			
Walla Walla, Wash.	26–27			0.39														.43			
Washington, D. C.	29			0.54														(*)			
Wichita, Kans.	20			0.38														.35			
Williston, N. Dak.	24			0.11														(*)			
Wilmington, N. C.	13			0.72														(*)			
Winnemucca, Nev.	4–5			0.27														.31			
Wytheville, Va.	4			1.79														(*)			
Yankton, S. Dak.	7–8			0.35														.33			
Yellowstone Park, Wyo.	11–12			0.03														(*)			
																		(*)			

* Self-register not working.

TABLE III.—*Data furnished by the Canadian Meteorological Service, December, 1914.*

Stations.	Pressure.			Temperature.						Precipitation.		
	Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Inches.	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	29.73	29.87	+0.07	24.8	−3.9	30.2	19.4	47	6	1.76	−3.27	8.0
Sydney, C. B. I.	30.00	30.04	+ .05	26.3	−1.9	32.6	20.0	52	4	1.92	−2.71	11.0
Halifax, N. S.	30.00	30.11	+ .15	22.4	−5.2	34.6	10.1	55	−14	4.32	−0.80	8.8
Yarmouth, N. S.	30.04	30.11	+ .13	29.2	−1.5	35.5	22.8	53	6	3.80	−1.24	15.3
Charlottetown, P. E. I.	30.02	30.06	+ .12	23.2	−1.1	28.9	17.4	47	− 9	1.58	−2.08	5.5
Chatham, N. B.	30.09	30.12	+ .18	17.4	+0.4	26.3	8.5	49	−24	1.63	−1.59	9.6
Father Point, Que.	30.05	30.08	+ .13	16.0	+0.6	22.6	9.4	44	−13	1.24	−1.59	10.4
Quebec, Que.	29.78	30.12	+ .11	14.4	−0.8	21.3	7.5	44	−23	2.26	−1.43	16.0
Montreal, Que.	29.94	30.16	+ .13	18.6	+0.3	24.8	12.3	48	−16	3.30	−0.35	27.8
Stonecliffe, Ont.	29.51	30.14	+ .13	14.7	−0.3	23.0	6.4	43	−40	2.10	−0.39	19.0
Ottawa, Ont.	29.89	30.24	+ .22	16.8	−0.2	25.0	8.6	45	−24	2.75	−0.16	19.1
Kingston, Ont.	29.84	30.18	+ .14	23.8	+0.1	30.2	17.3	51	−20	2.47	−0.77	17.1
Toronto, Ont.	29.74	30.14	+ .09	25.7	−1.3	31.5	20.0	54	− 7	1.76	−1.15	15.2
White River, Ont.	28.70	30.09	+ .12	4.2	−5.5	18.2	−10.0	41	−46	1.50	−0.21	13.0
Port Stanley, Ont.	29.48	30.15	+ .08	24.4	−4.0	31.3	17.6	54	−25	2.32	−0.10	17.2
Southampton, Ont.	29.39	.....	.....	24.2	−2.5	29.5	18.9	53	− 2	3.91	−0.07	36.4
Parry Sound, Ont.	29.40	30.14	+ .13	20.5	−0.7	29.3	11.7	51	−24	3.94	−0.54	38.5
Port Arthur, Ont.	29.43	30.18	+ .19	11.5	−1.7	20.0	3.0	44	−20	0.23	−0.64	1.3
Winnipeg, Man.	29.33	30.23	+ .21	1.2	−2.9	9.0	− 6.6	29	−27	1.40	+0.49	14.0
Minnedosa, Man.	28.27	30.21	+ .19	2.2	−3.5	10.2	− 5.8	25	−32	0.33	−0.29	3.3
Qu'Appelle, Sask.	27.77	30.16	+ .16	3.2	−4.2	10.7	− 4.4	26	−36	0.41	−0.11	4.1
Medicine Hat, Alberta	27.77	30.17	+ .20	13.0	−5.2	21.3	4.6	42	−12	0.90	+0.35	9.0
Swift Current, Sask.	27.44	30.16	+ .17	9.6	−6.4	17.2	2.0	42	−16	0.97	+0.19	9.7
Calgary, Alberta	26.40	30.12	+ .18	13.0	−5.2	21.6	4.5	38	−10	0.75	+0.16	7.5
Banff, Alberta	25.35	30.20	+ .26	9.7	−9.4	18.1	1.3	31	−18	0.28	−0.93	2.8
Edmonton, Alberta	27.73	30.16	+ .23	9.0	−4.1	16.6	1.3	34	−20	1.49	+0.79	14.9
Prince Albert, Sask.	28.51	30.18	+ .17	0.2	−2.6	4.0	− 3.6	22	−40	0.56	−0.18	5.6
Battleford, Sask.	28.35	30.20	+ .21	5.9	+0.5	12.6	− 0.9	33	−28	0.82	+0.50	8.2
Kamloops, B. C.	28.92	30.19	+ .25	21.5	−7.4	26.2	16.8	45	2	0.58	−0.20	5.8
Victoria, B. C.	29.79	29.99	+ .02	29.6	−1.6	43.0	36.2	49	30	0.59	−7.39	1.0
Barkerville, B. C.	25.61	30.09	+ .21	11.8	−9.1	16.9	6.7	32	− 8	3.10	−0.07	31.0
Hamilton, Bermuda	29.98	30.14	+ .02	67.0	+2.3	72.3	61.6	76	56	10.46	+5.97	.....

Chart I. Hydrographs of Several Principal Rivers, December, 1914.

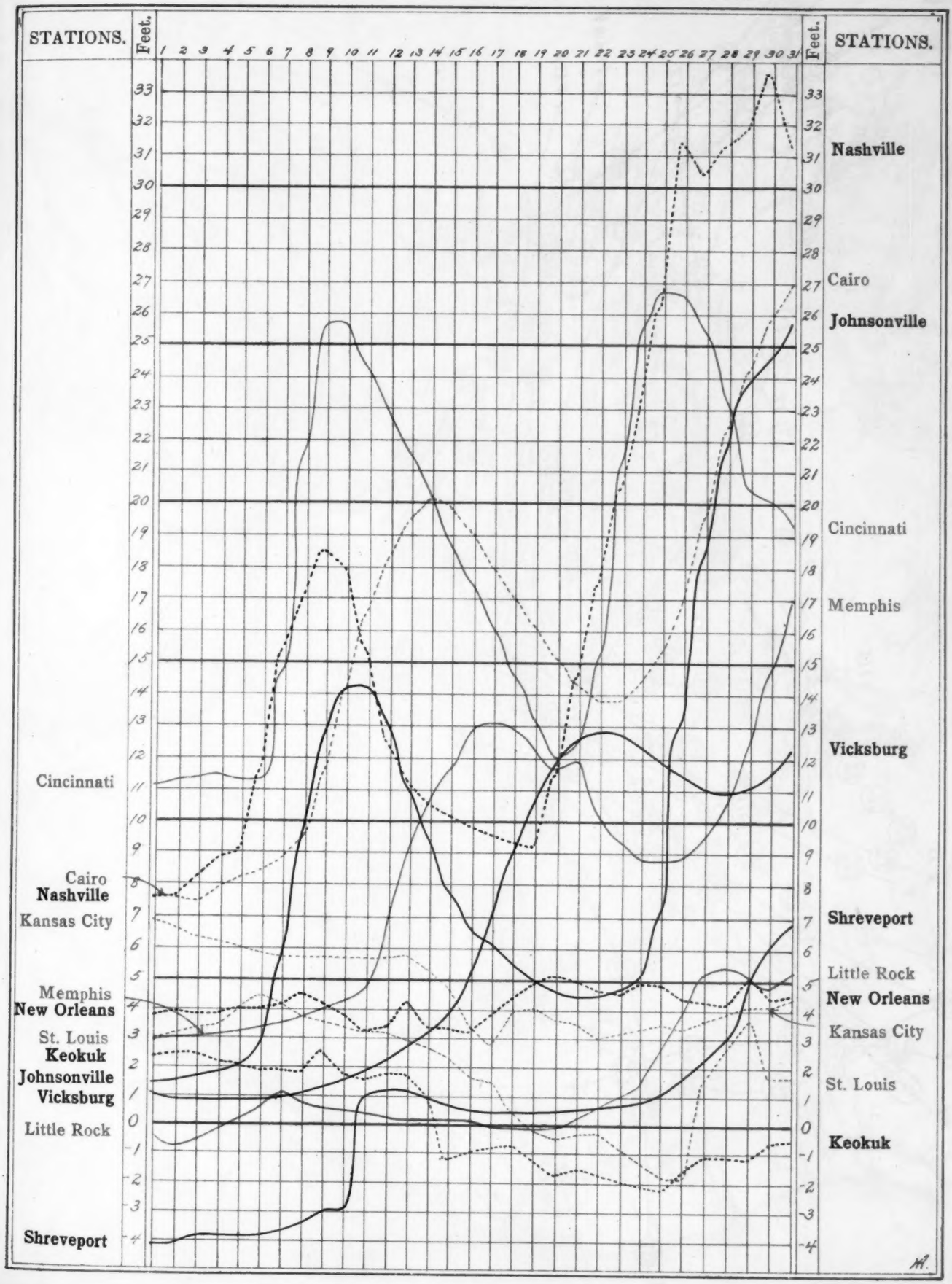


Chart II. Tracks of Centers of High Areas, December, 1914.

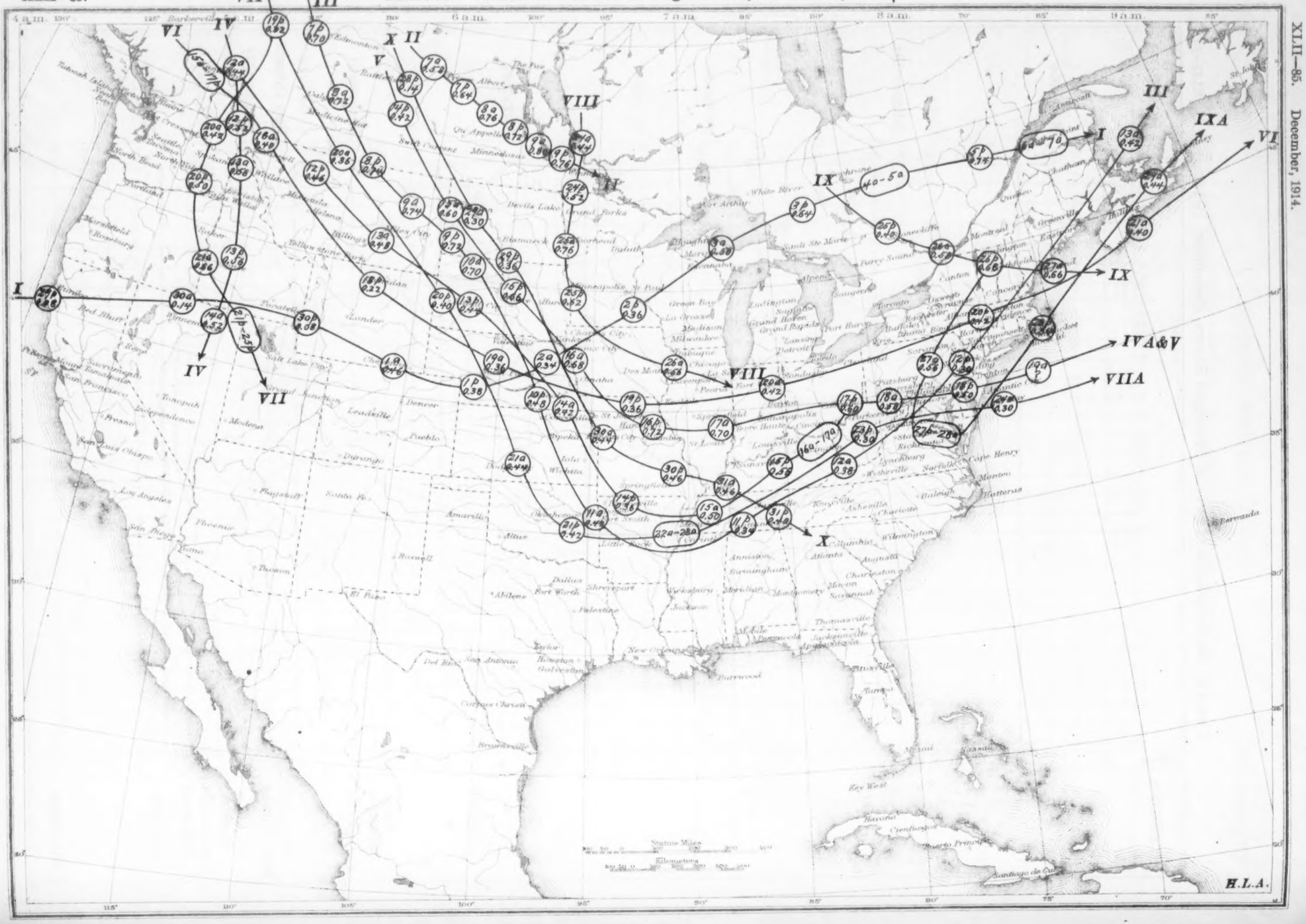


Chart III. Tracks of Centers of Low Areas, December, 1914.

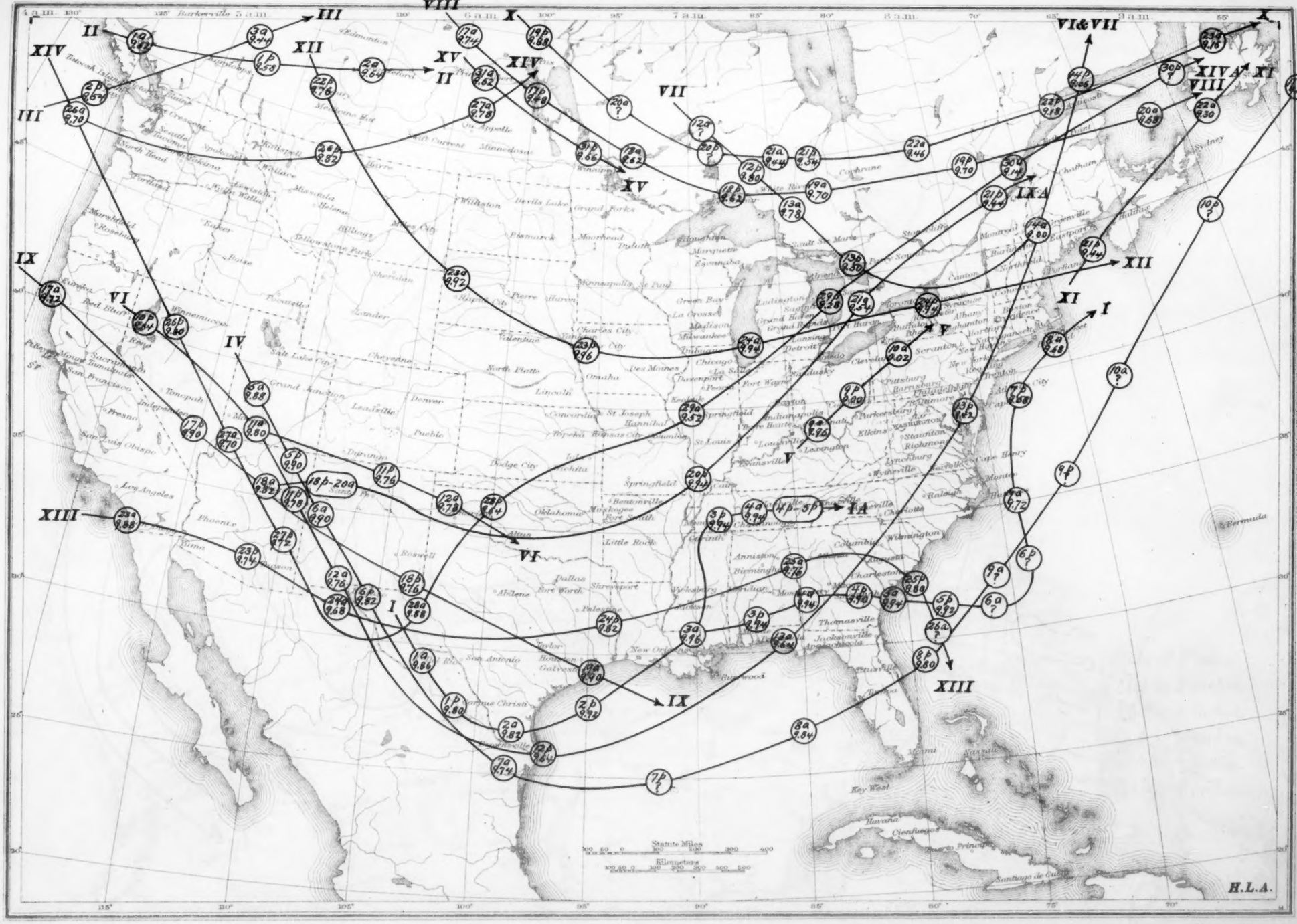


Chart IV. Departure of the Mean Temperature from the Normal, December, 1914.

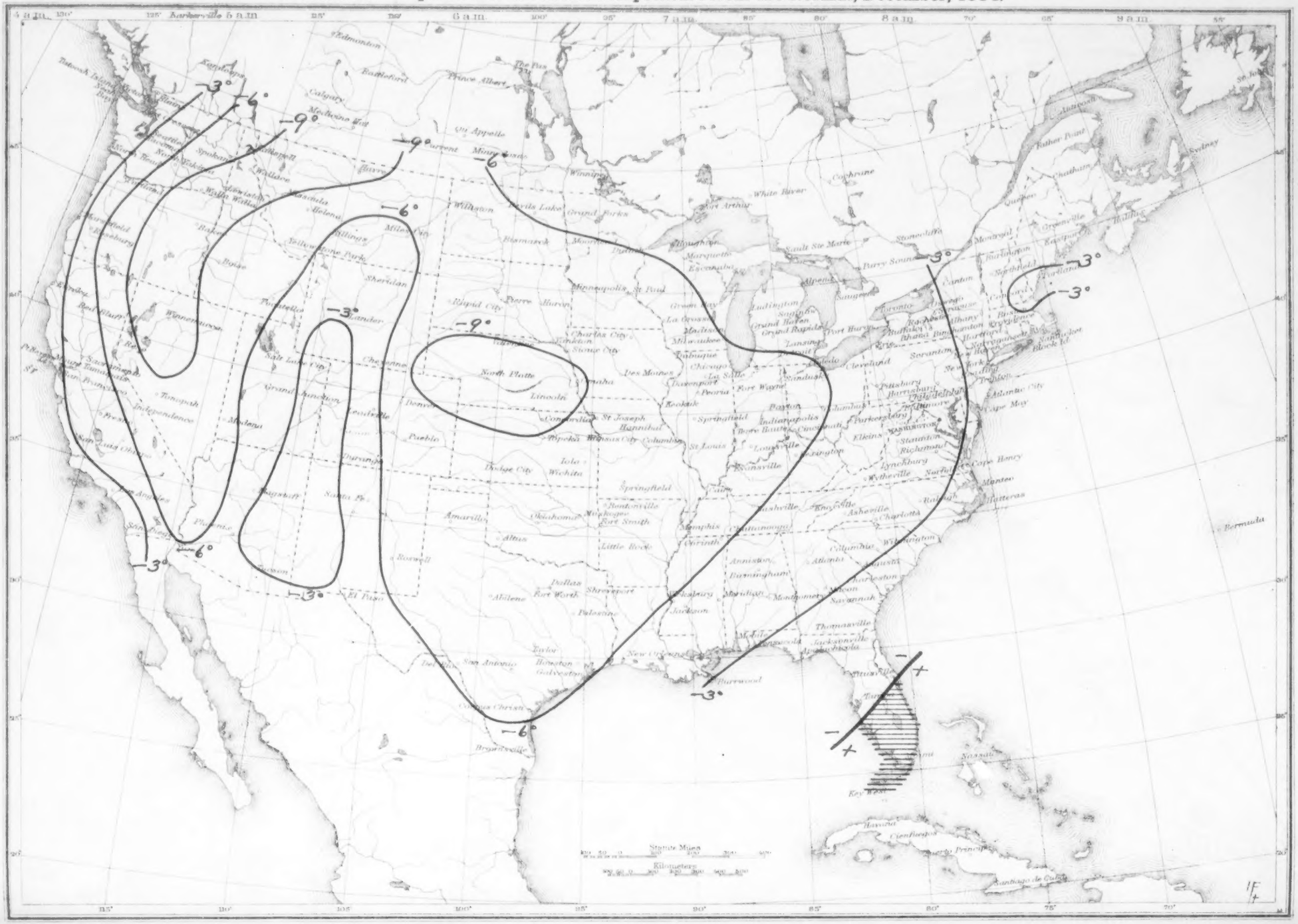


Chart V. Total Precipitation, inches, December, 1914.

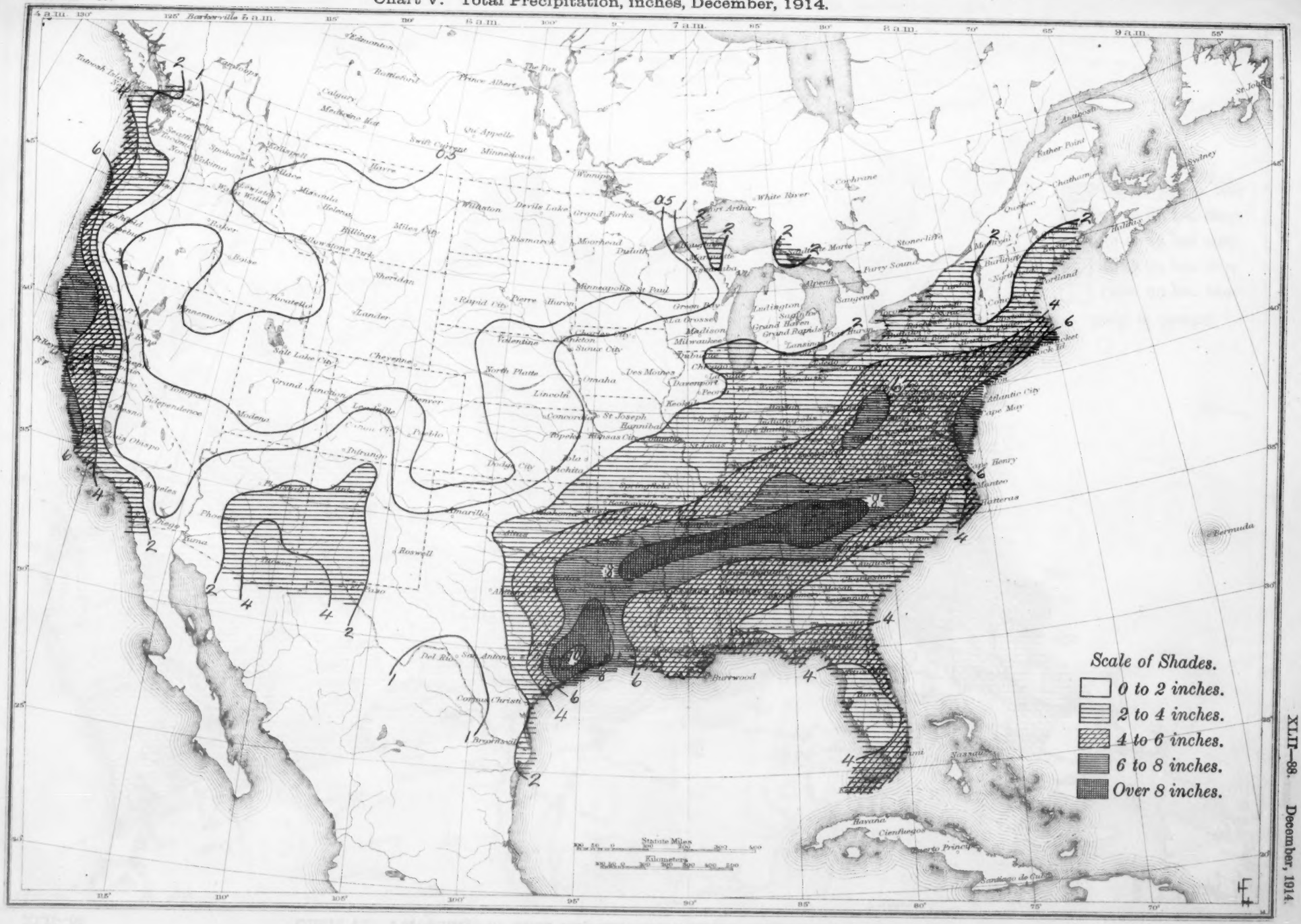


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, December, 1914.

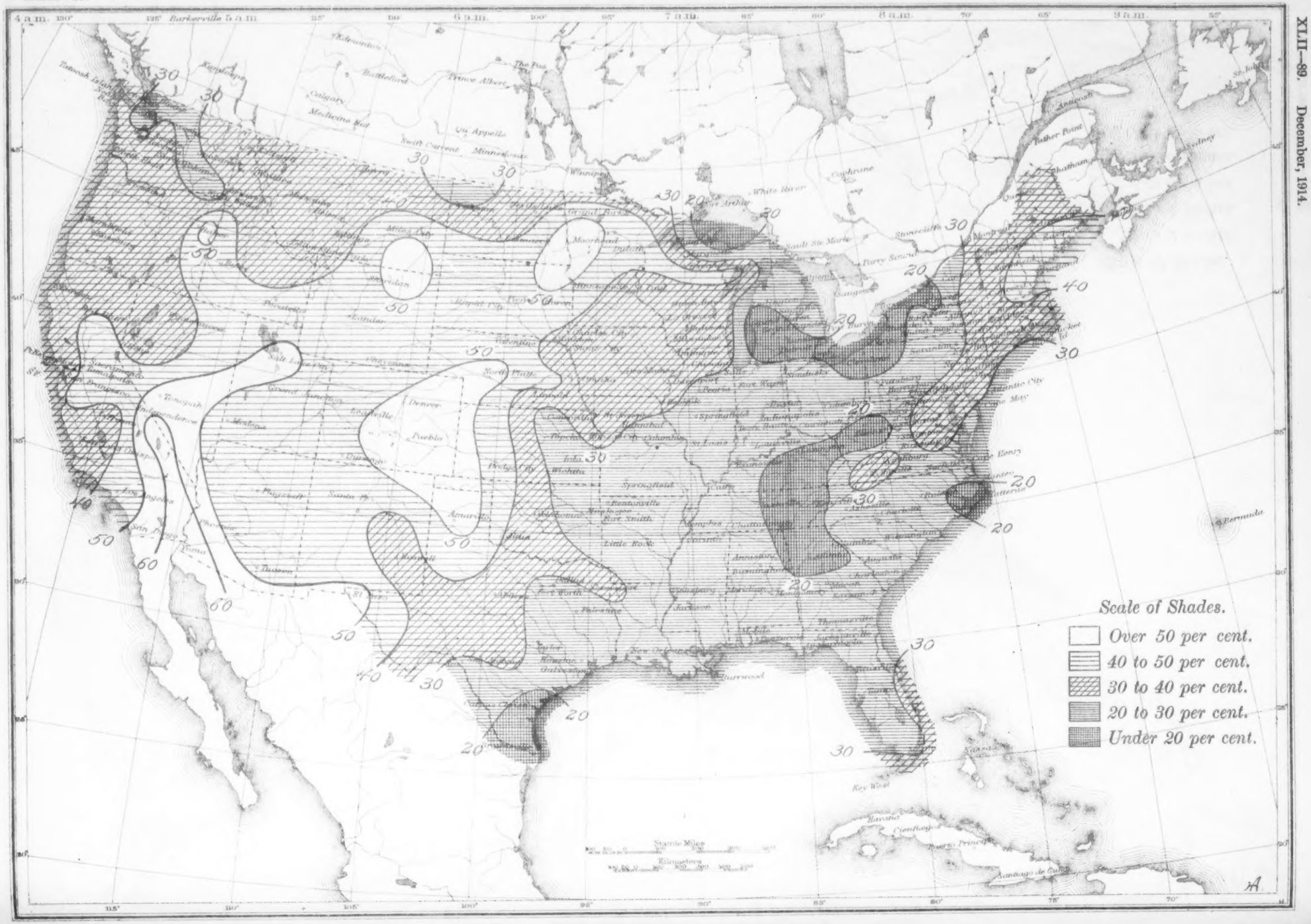


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, December, 1914.

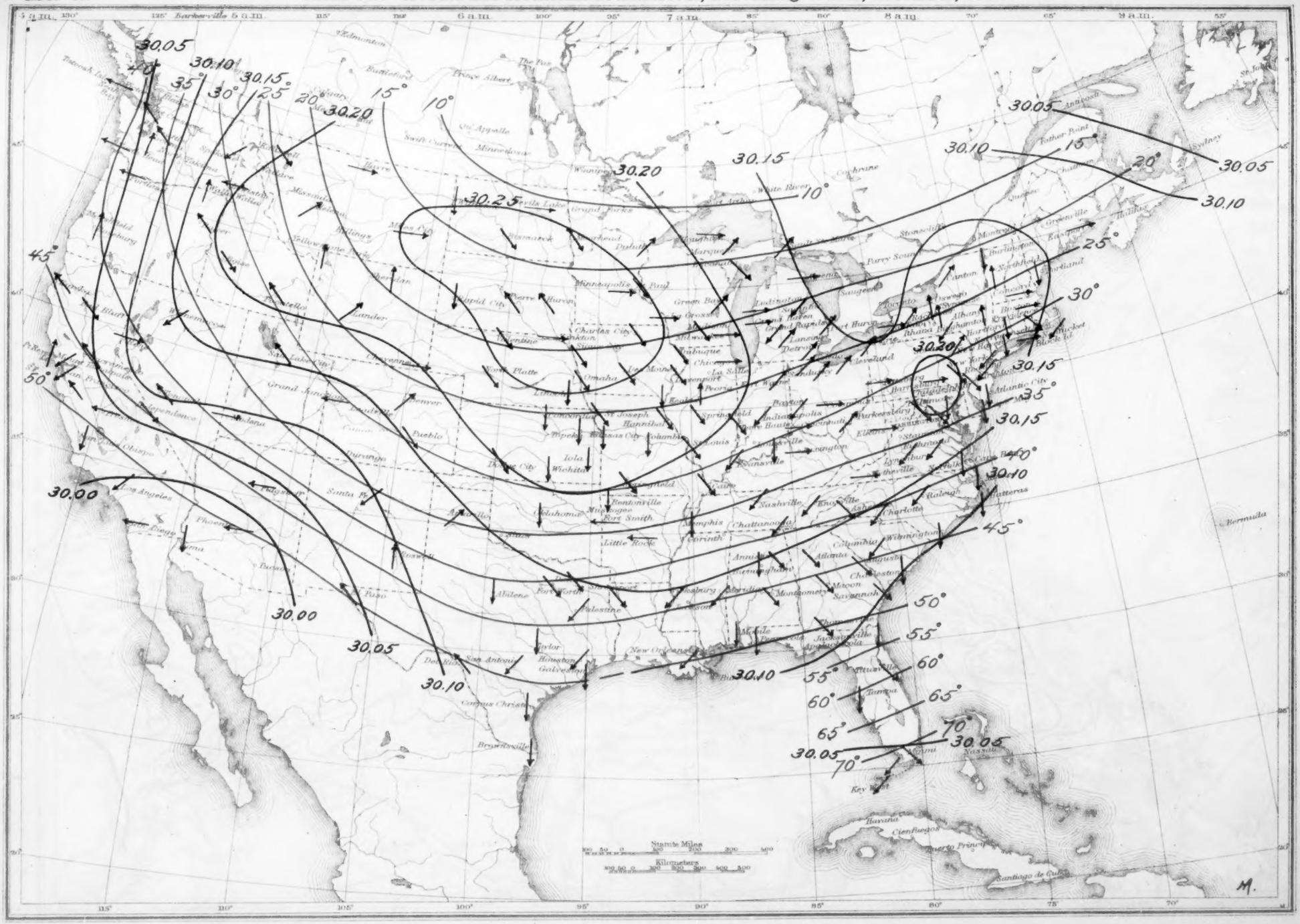
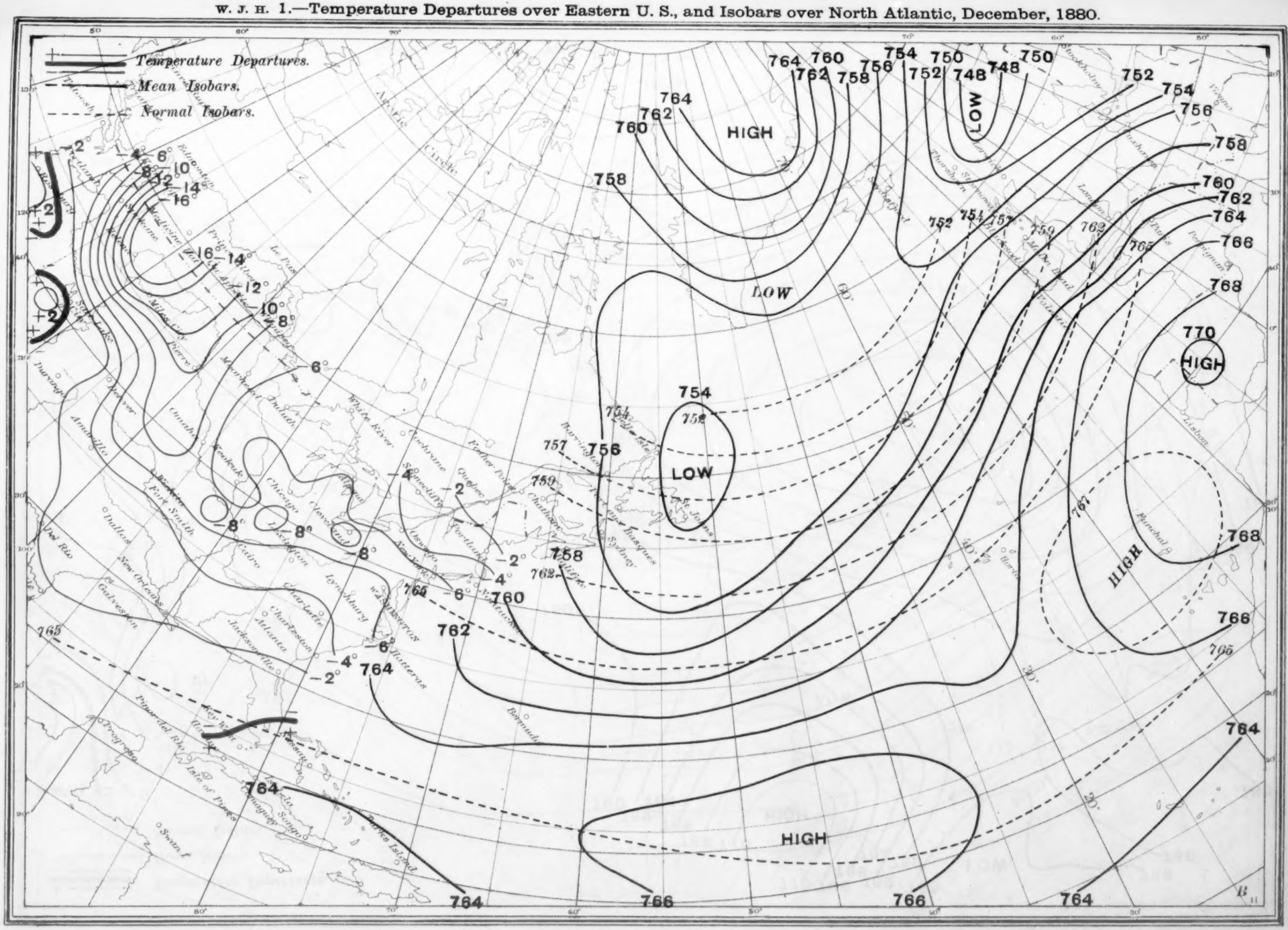


Chart VIII. Total Snowfall, inches, December, 1914.

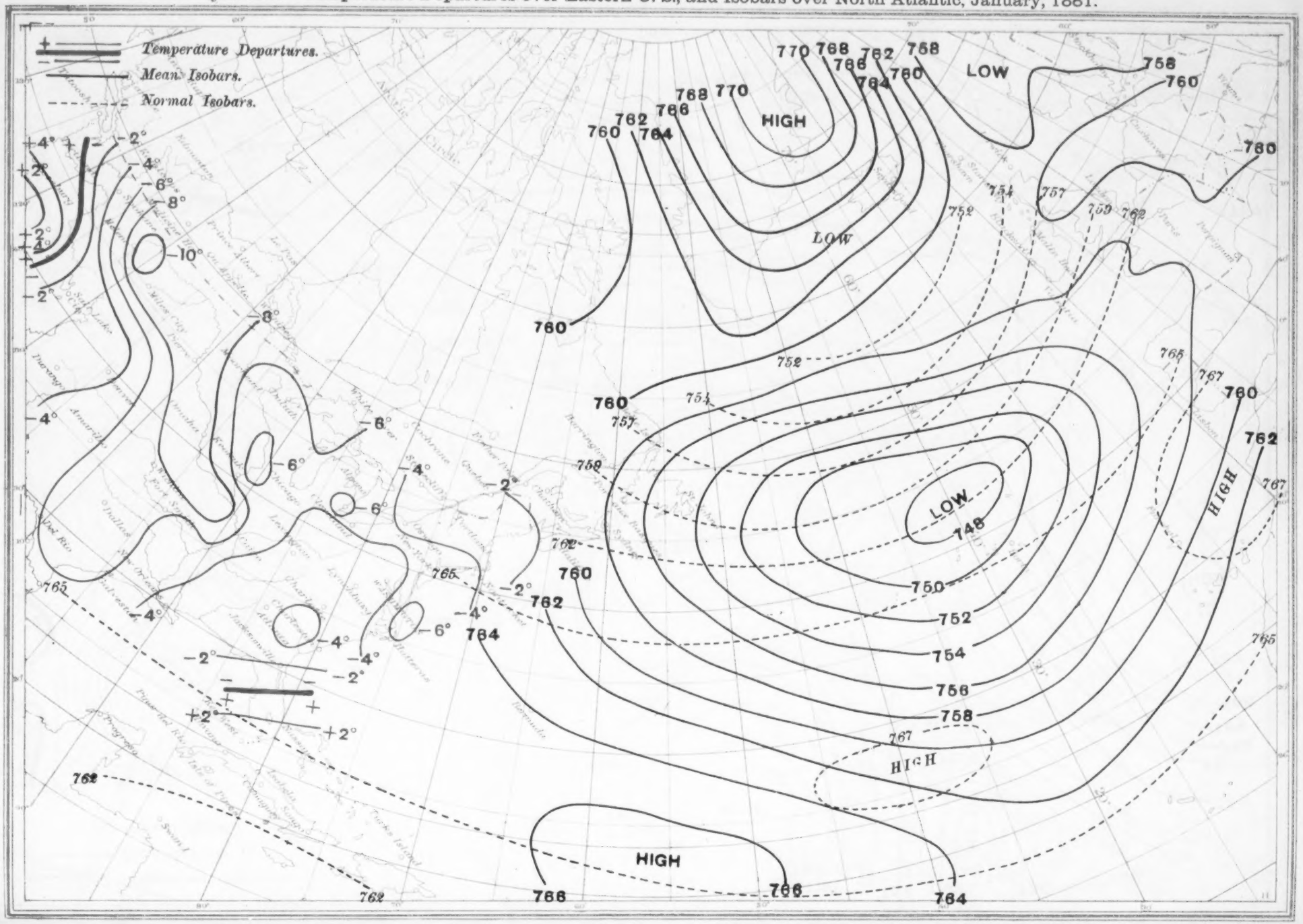
XLII—91. December, 1914.

W. J. H. 1.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1880.

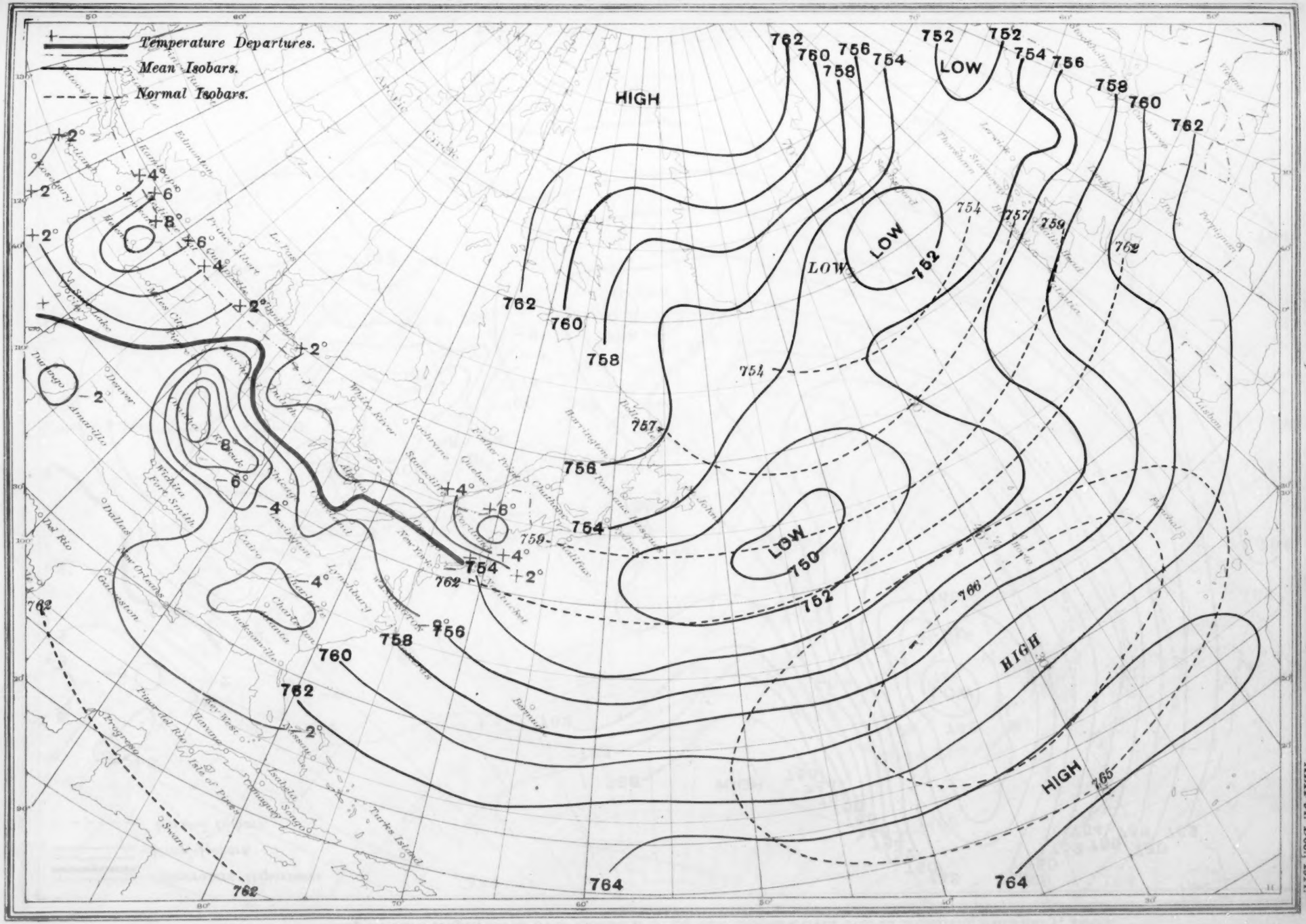


XLII-92. Dec., 1914.

W. J. H. 2.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1881.

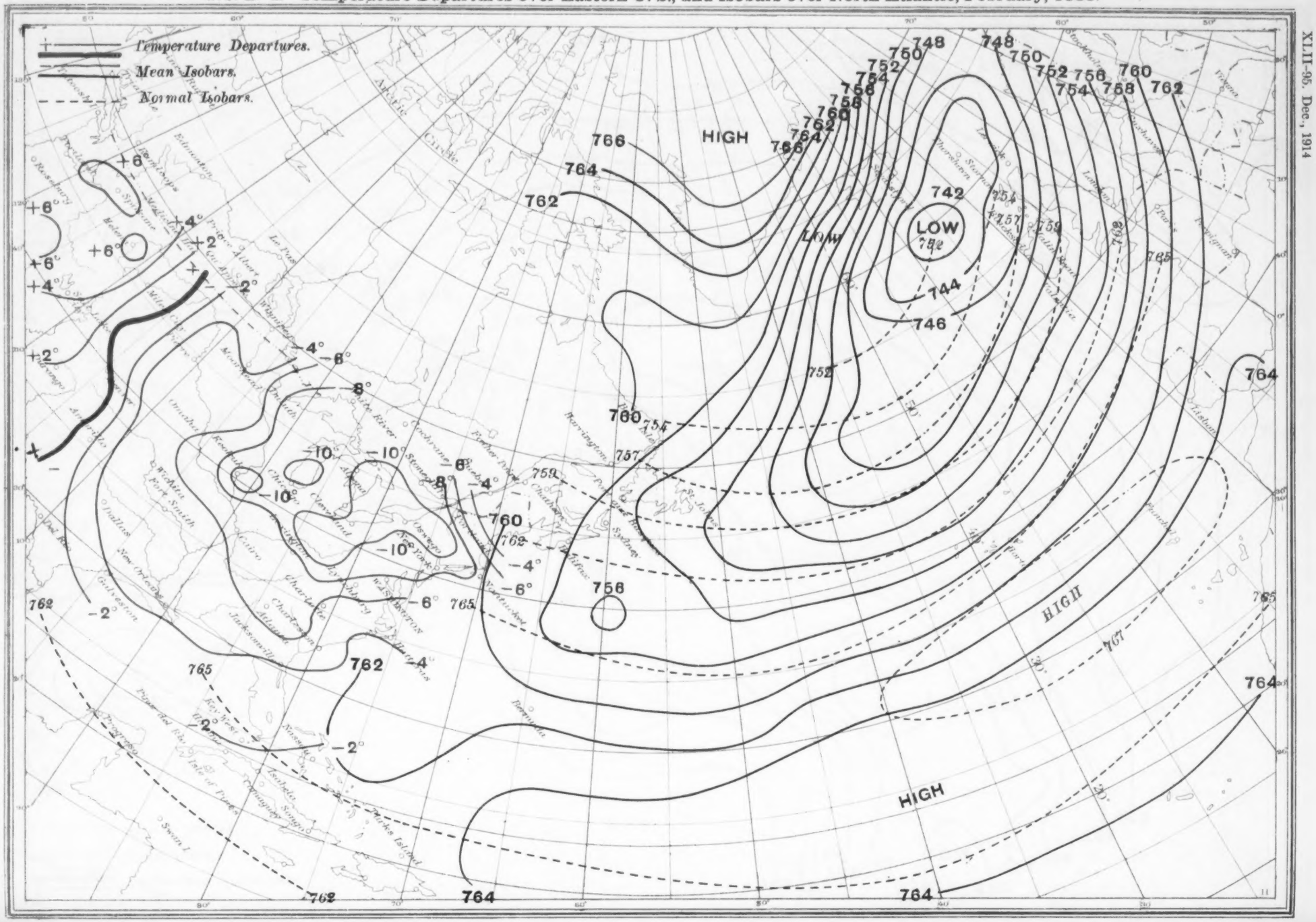


W. J. H. 3.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, March, 1881.

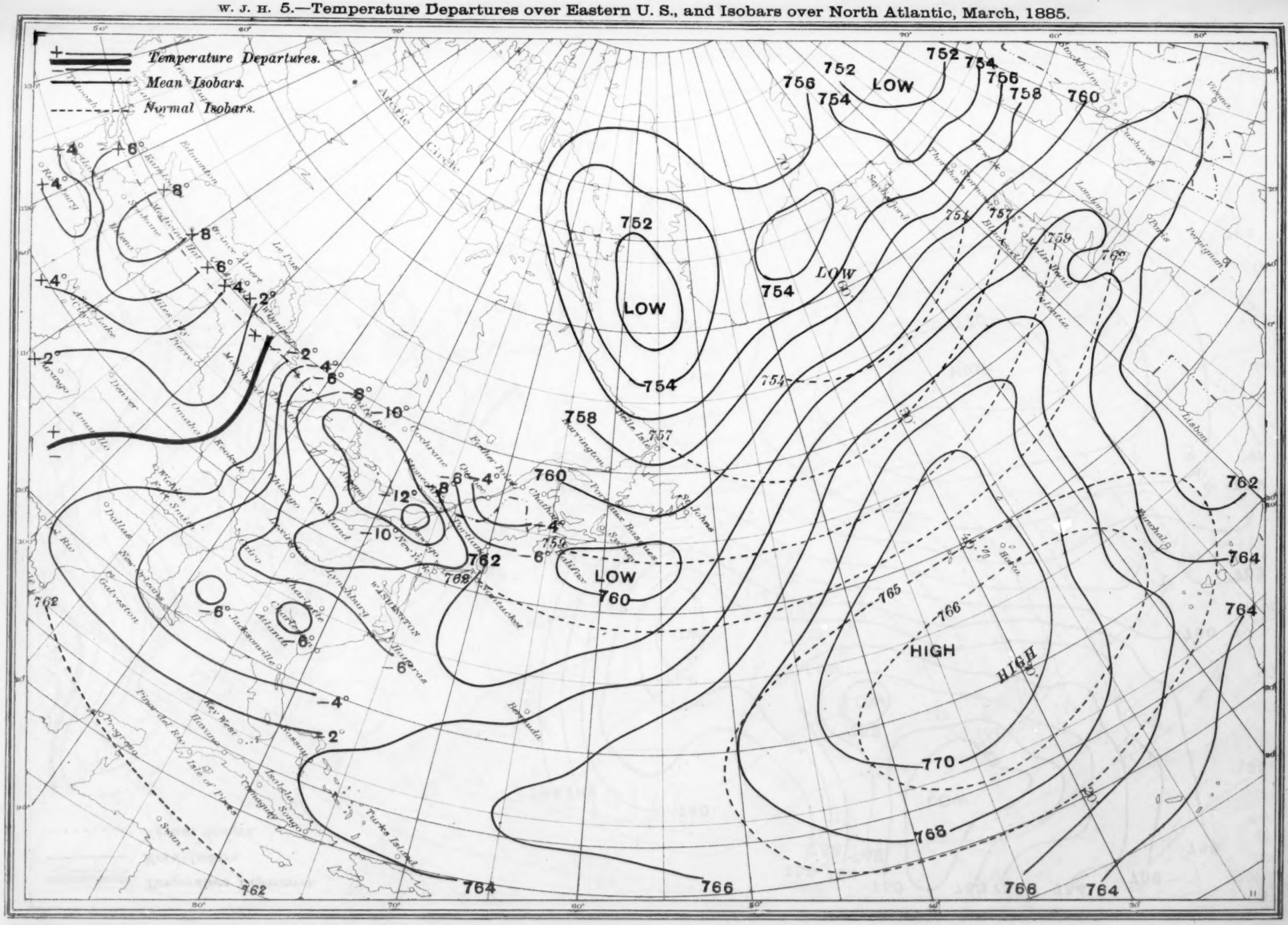


XLII-94. Dec., 1914.

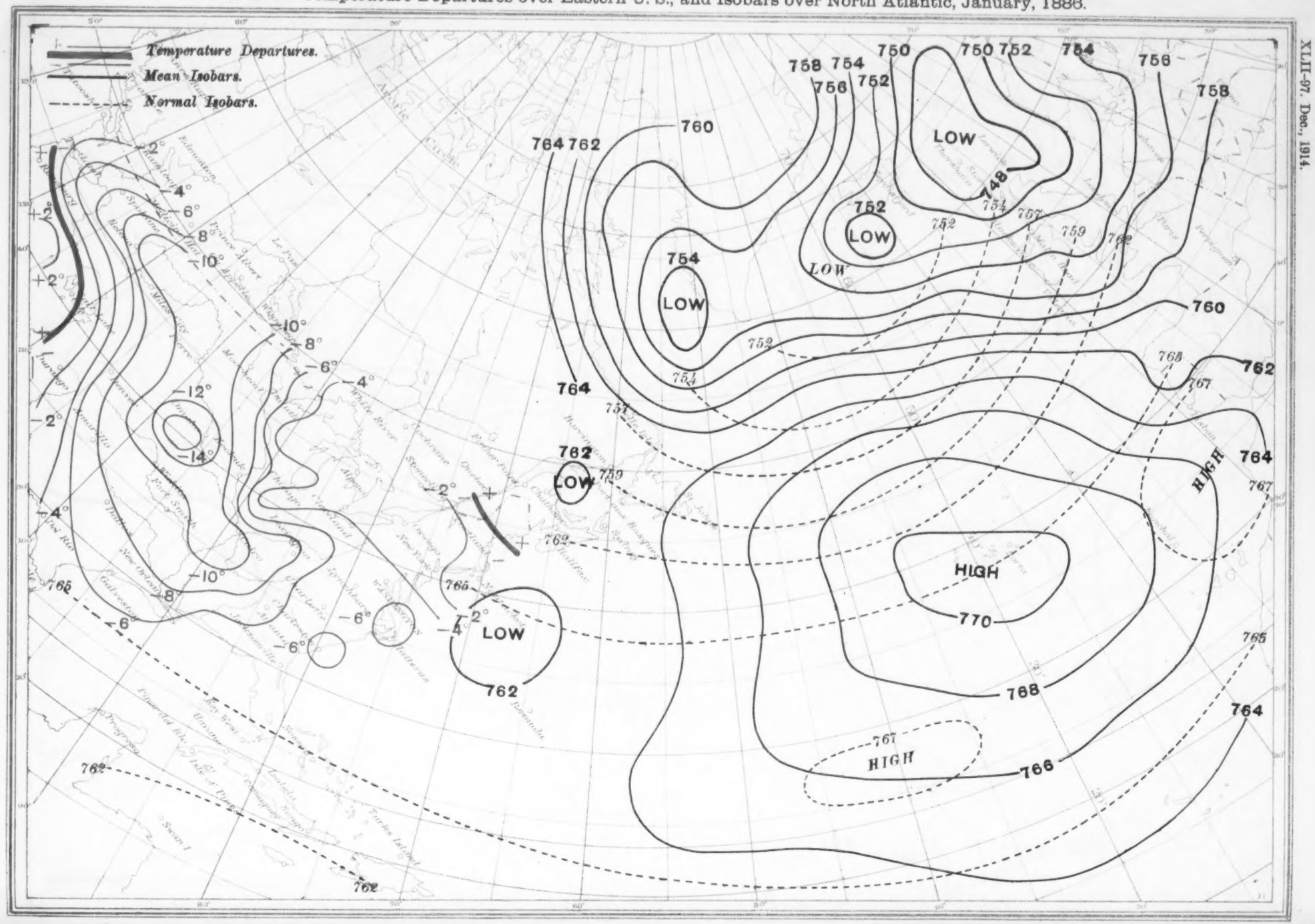
W. J. H. 4.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1885.



W. J. H. 5.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, March, 1885.

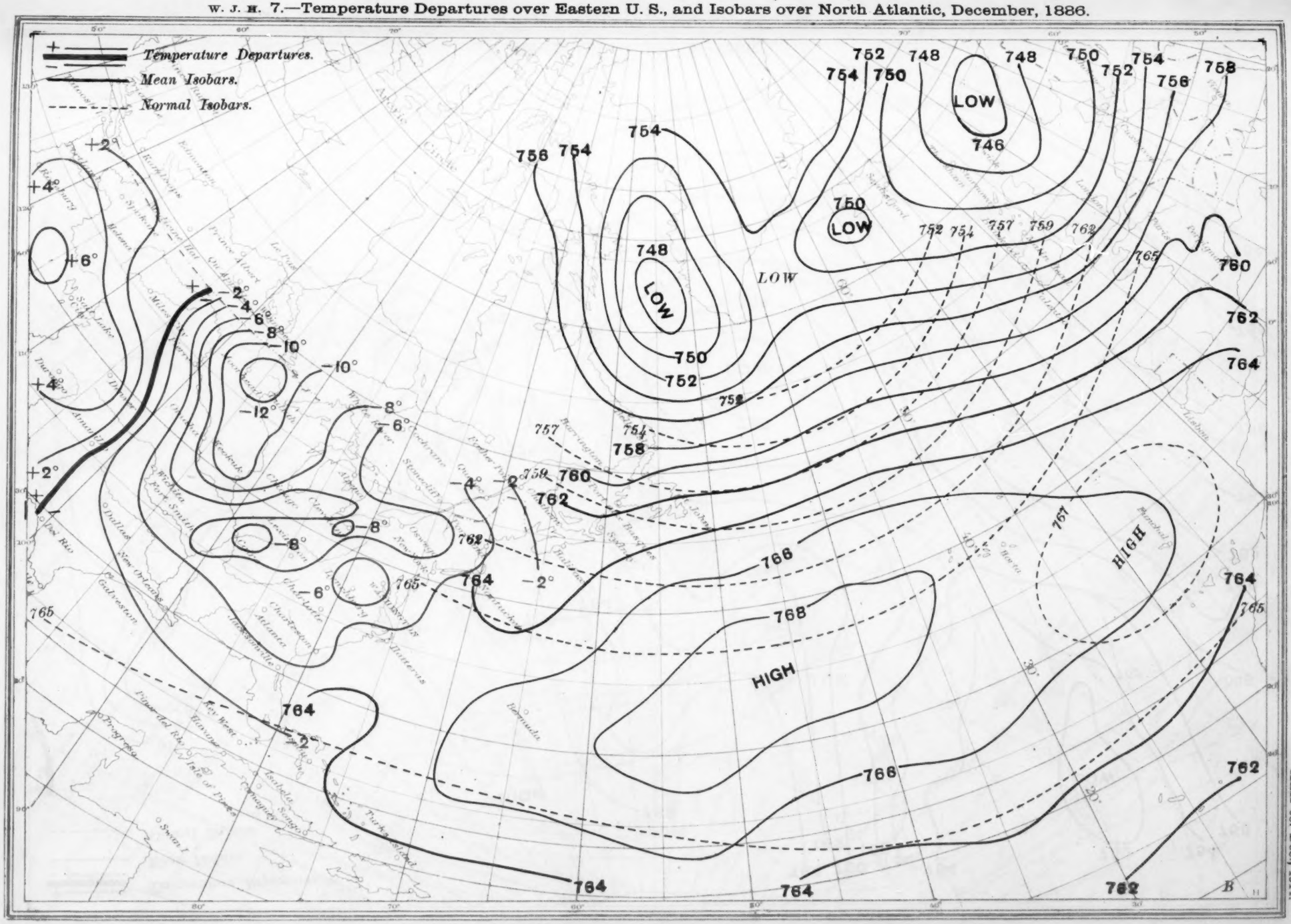


W. J. H. 6.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1886.



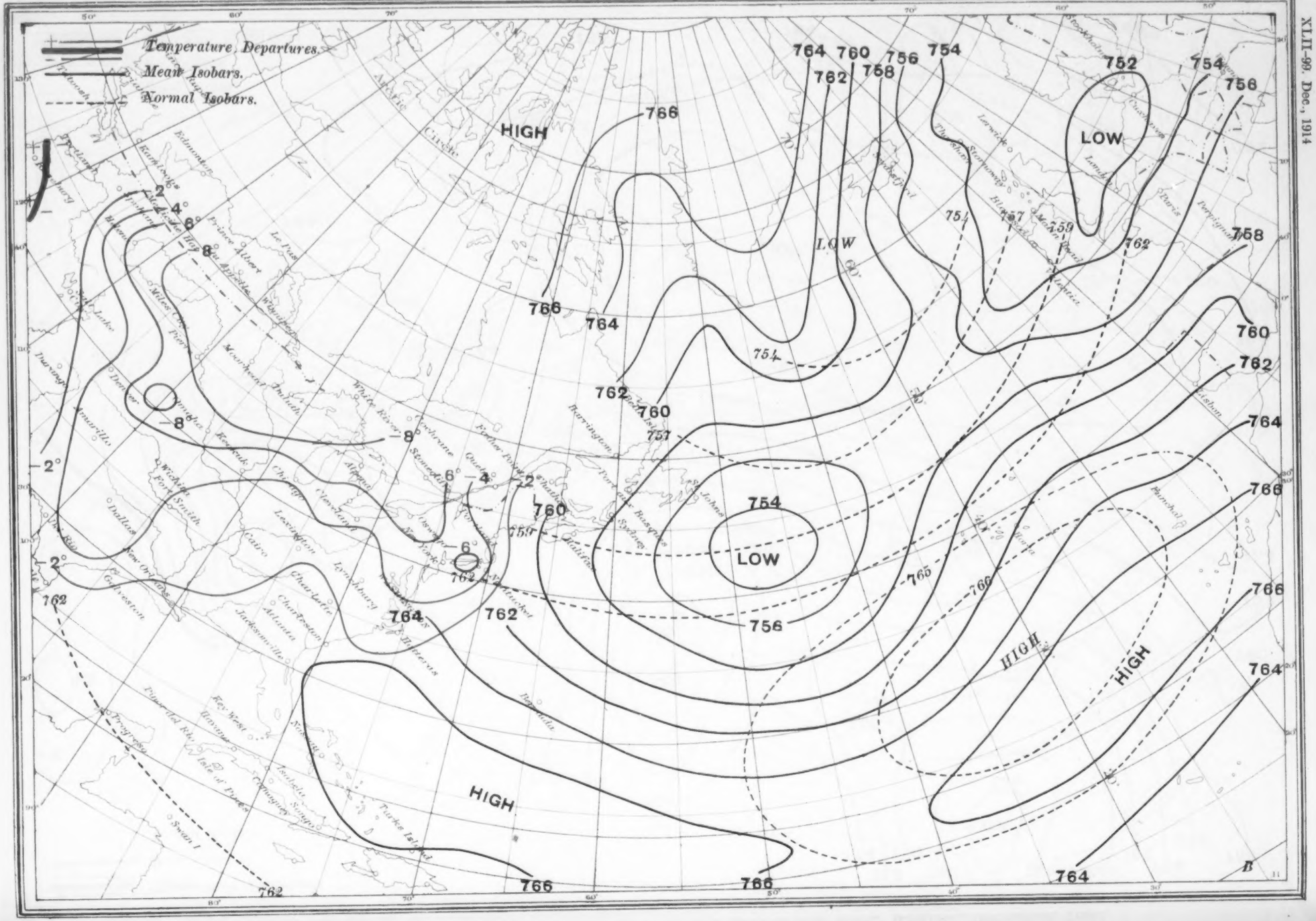
XLII-97. Dec., 1914.

W. J. H. 7.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1886.



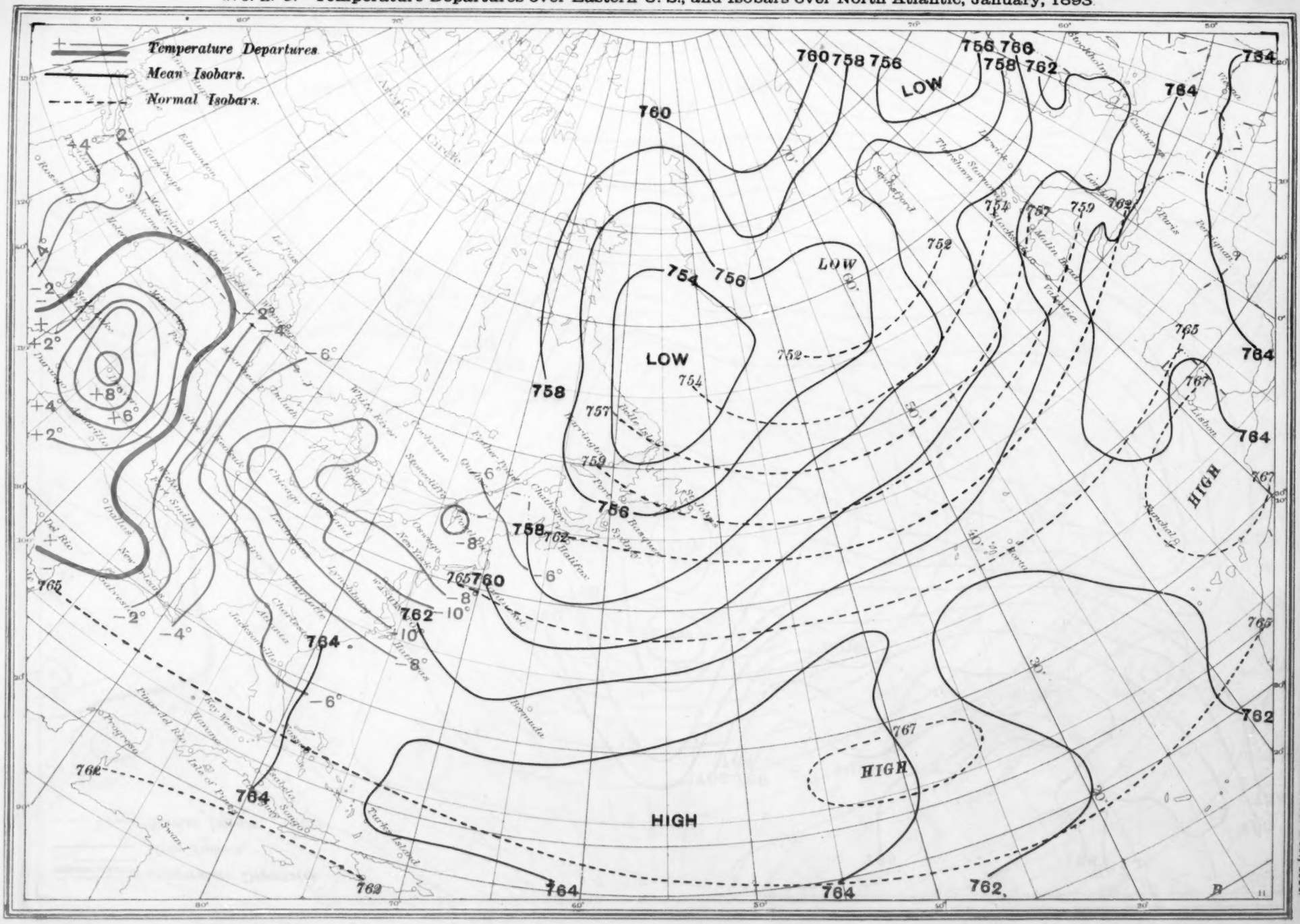
XLII–98. Dec., 1914.

W. J. H. 8.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, March, 1888.



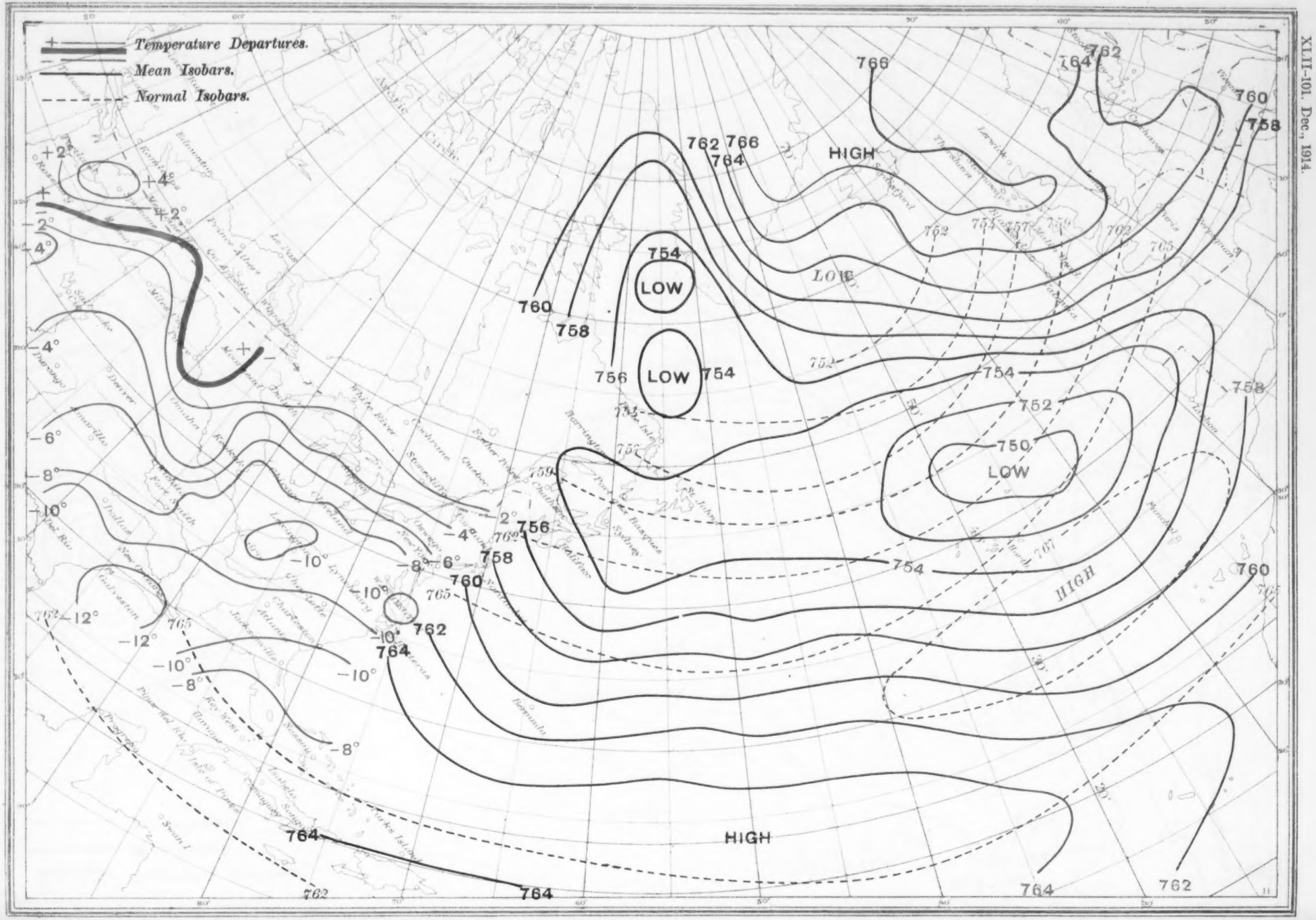
XLII-99. Dec., 1914

W. J. H. 9.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1893.



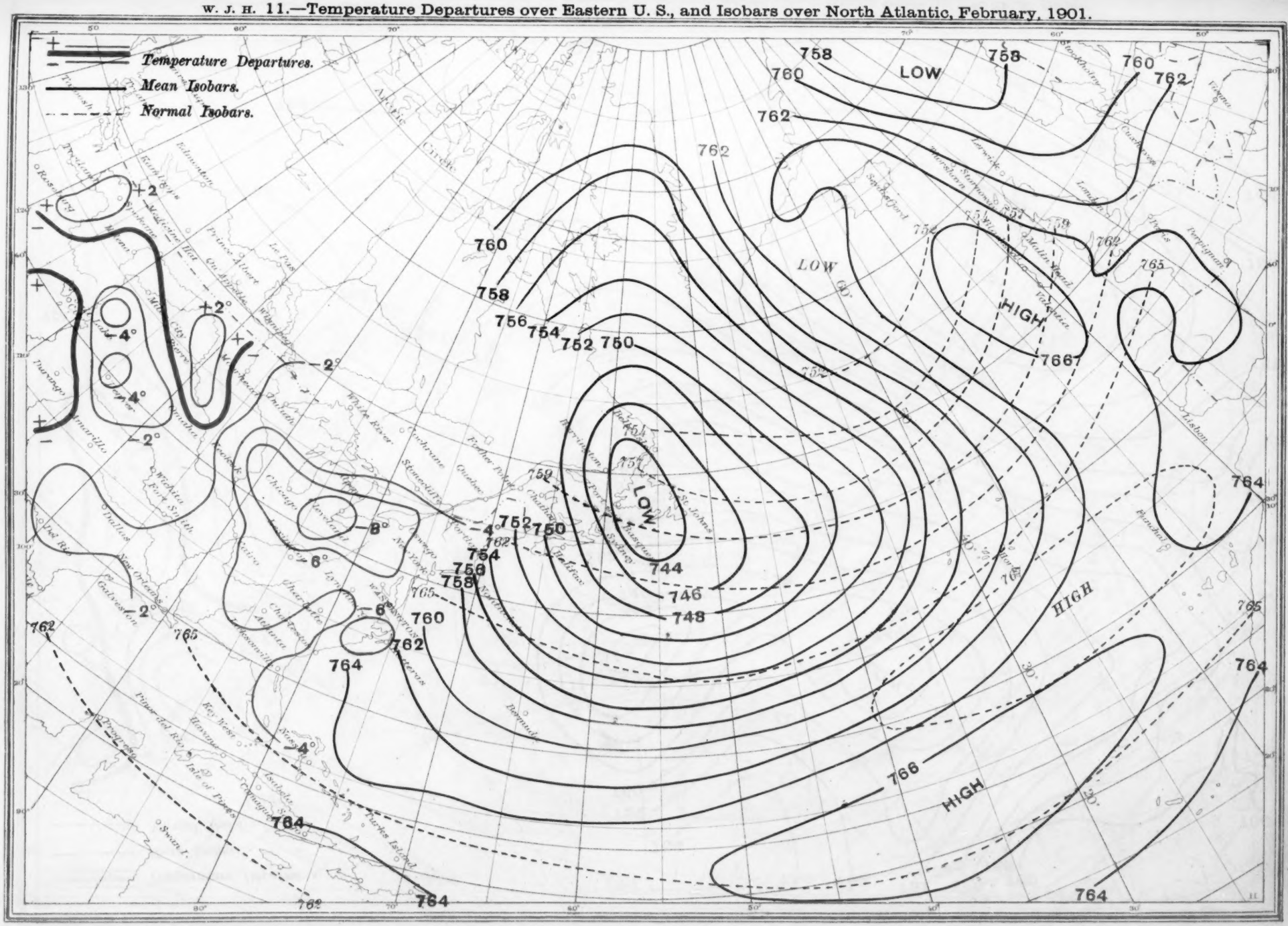
XLII-100. Dec., 1914.

W. J. H. 10.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1895.



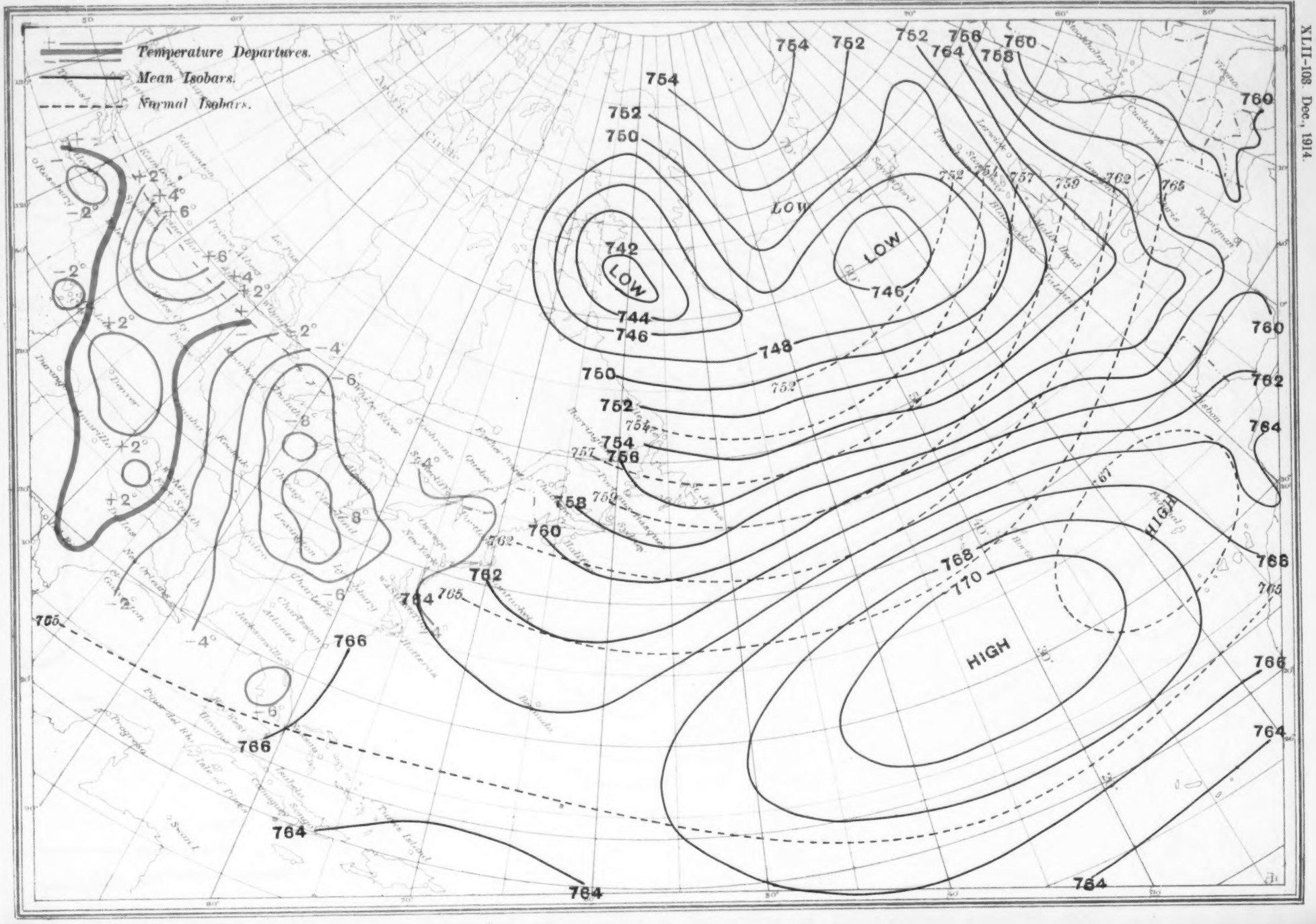
XLII–101. Dec., 1914.

W. J. H. 11.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1901.



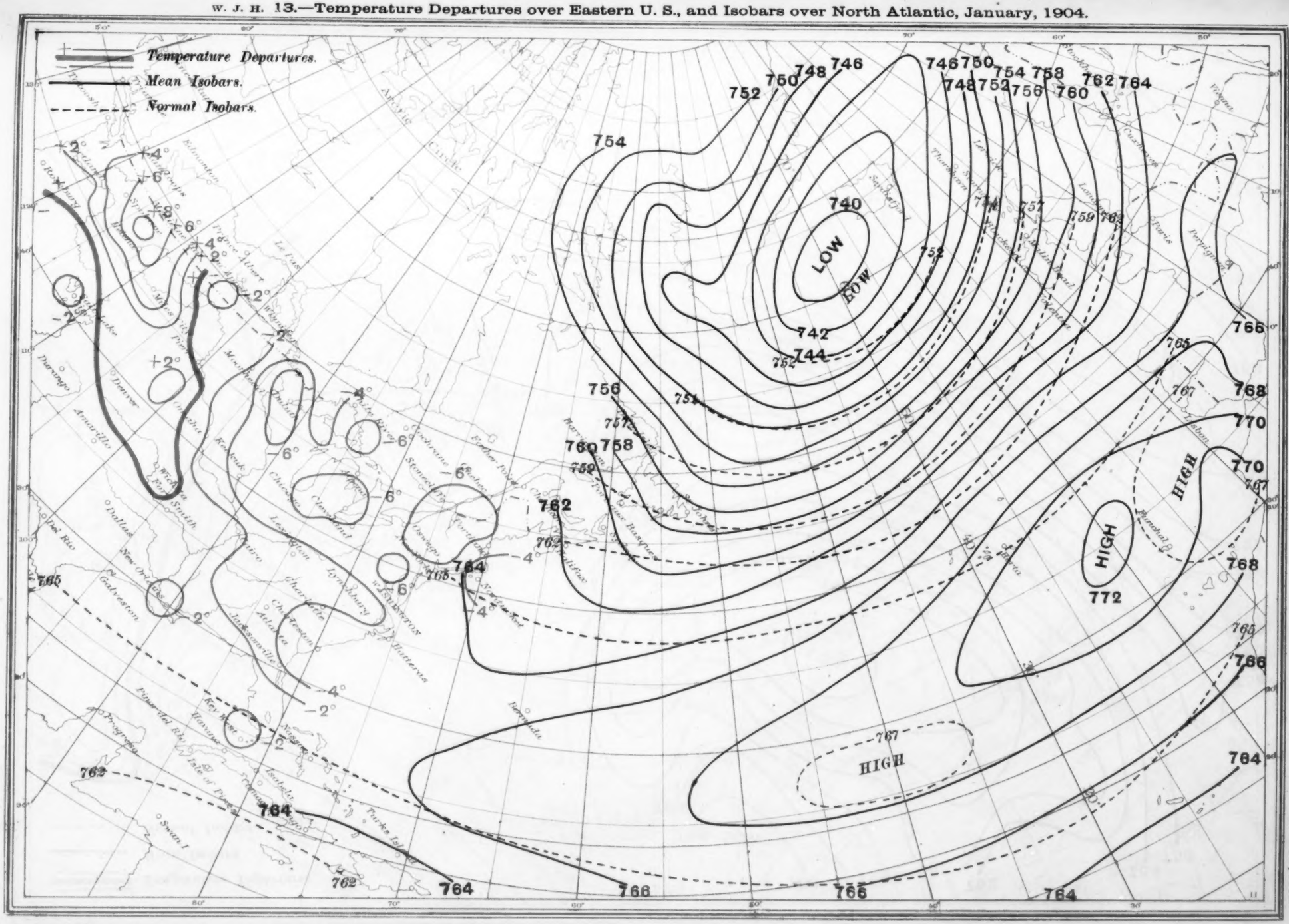
XLII-102. Dec., 1914.

W. J. H. 12.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1903.

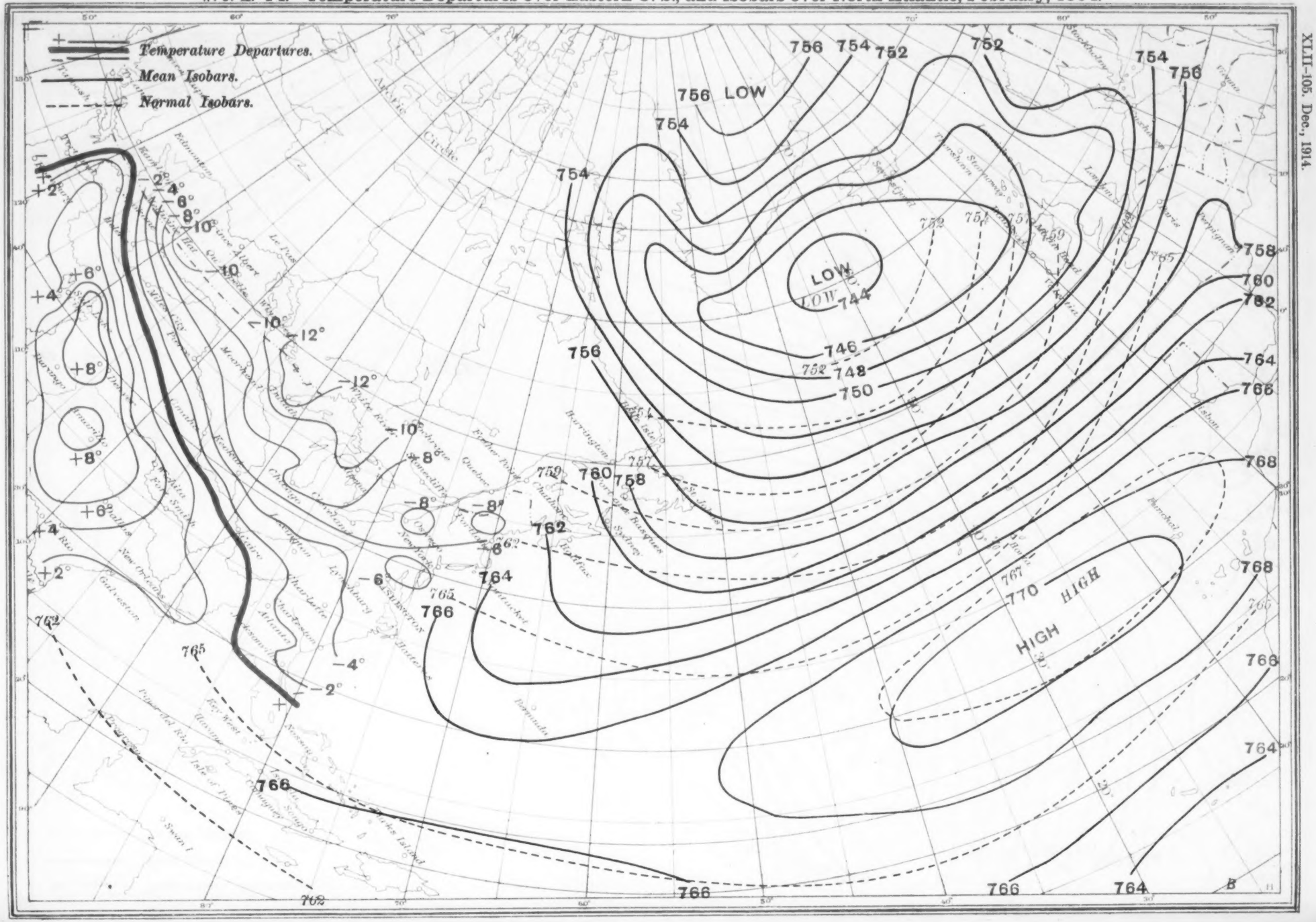


XLII–108 Dec., 1914.

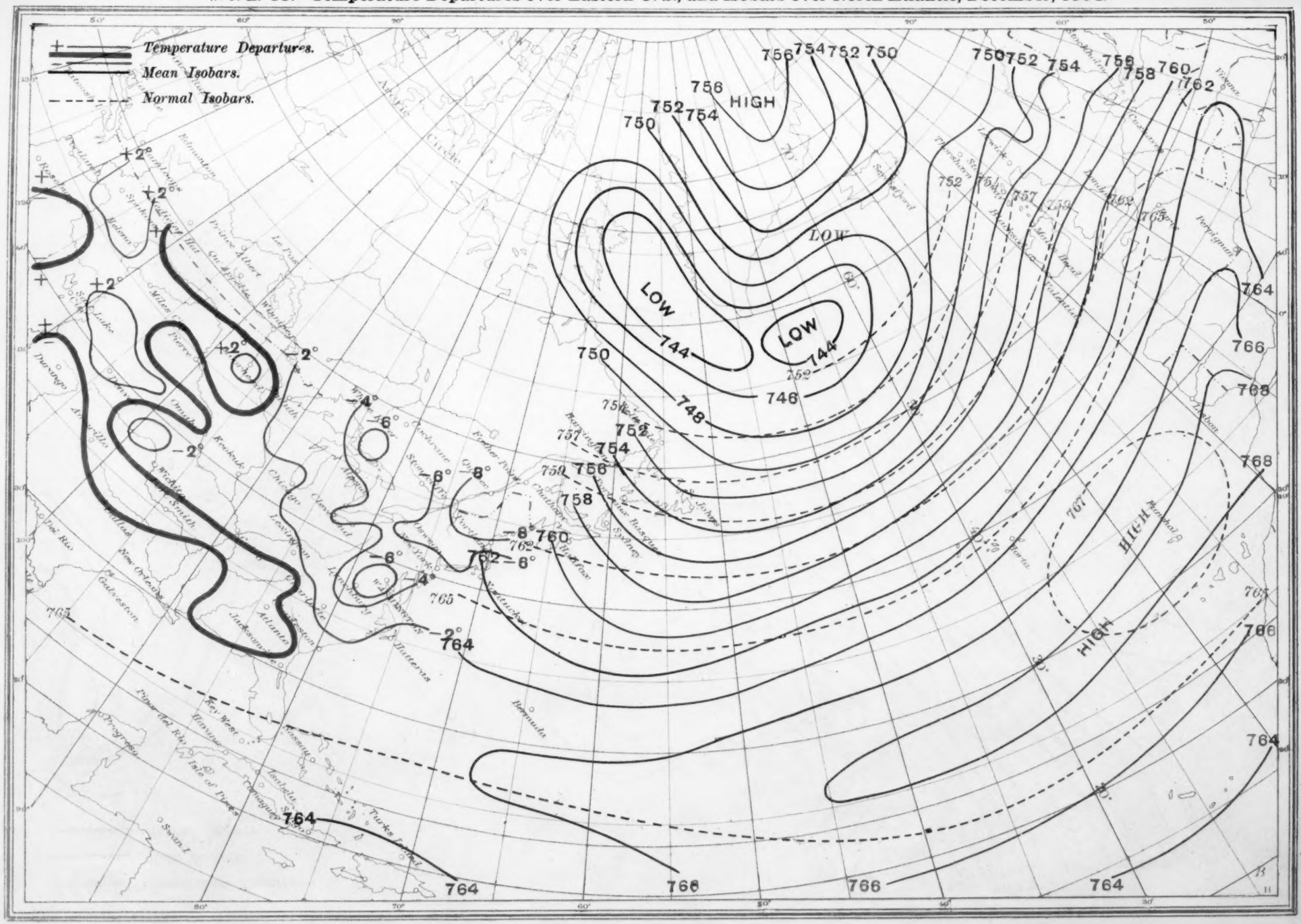
W. J. H. 13.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1904.



W. J. H. 14.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1904.

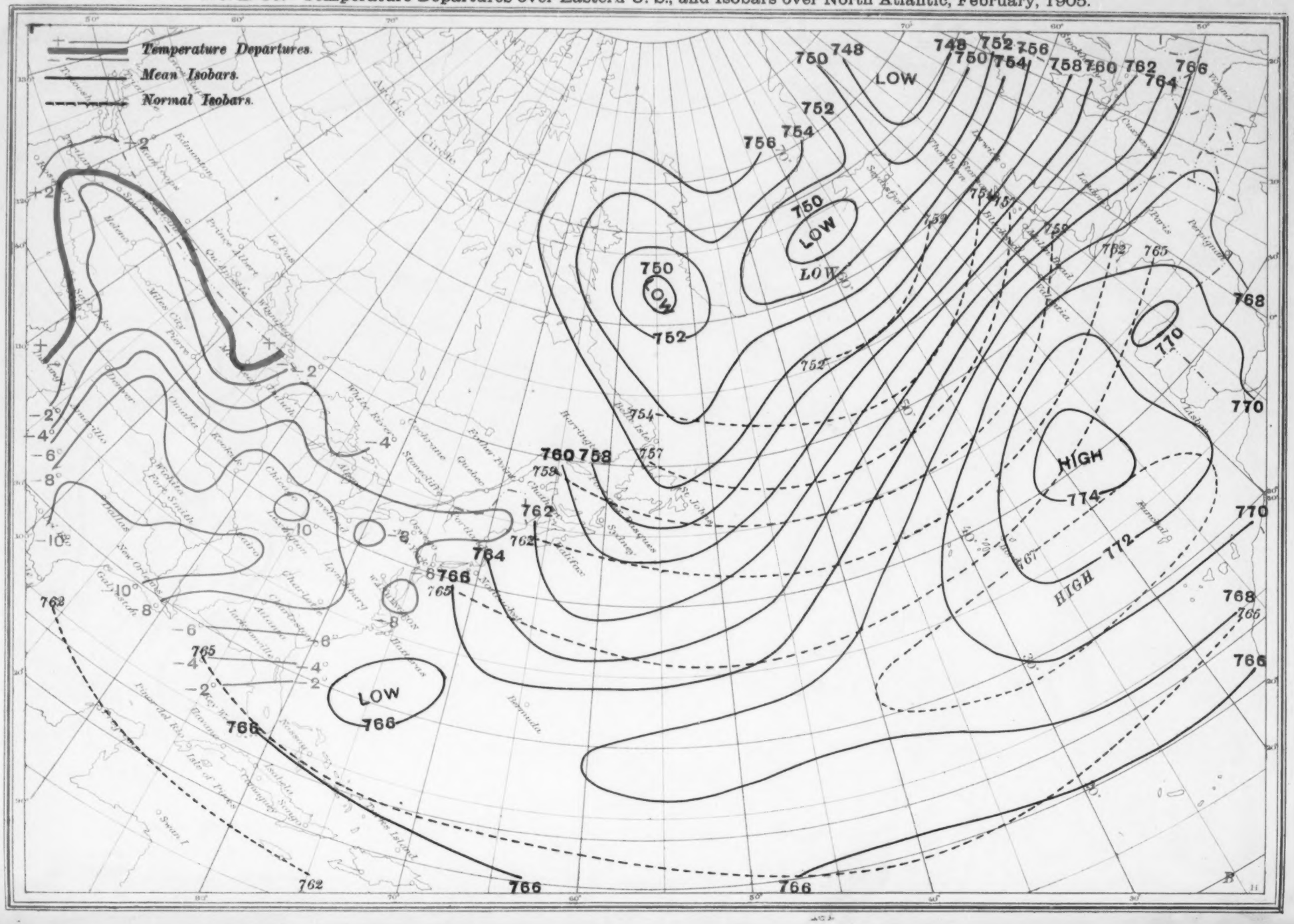


W. J. H. 15.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1904.

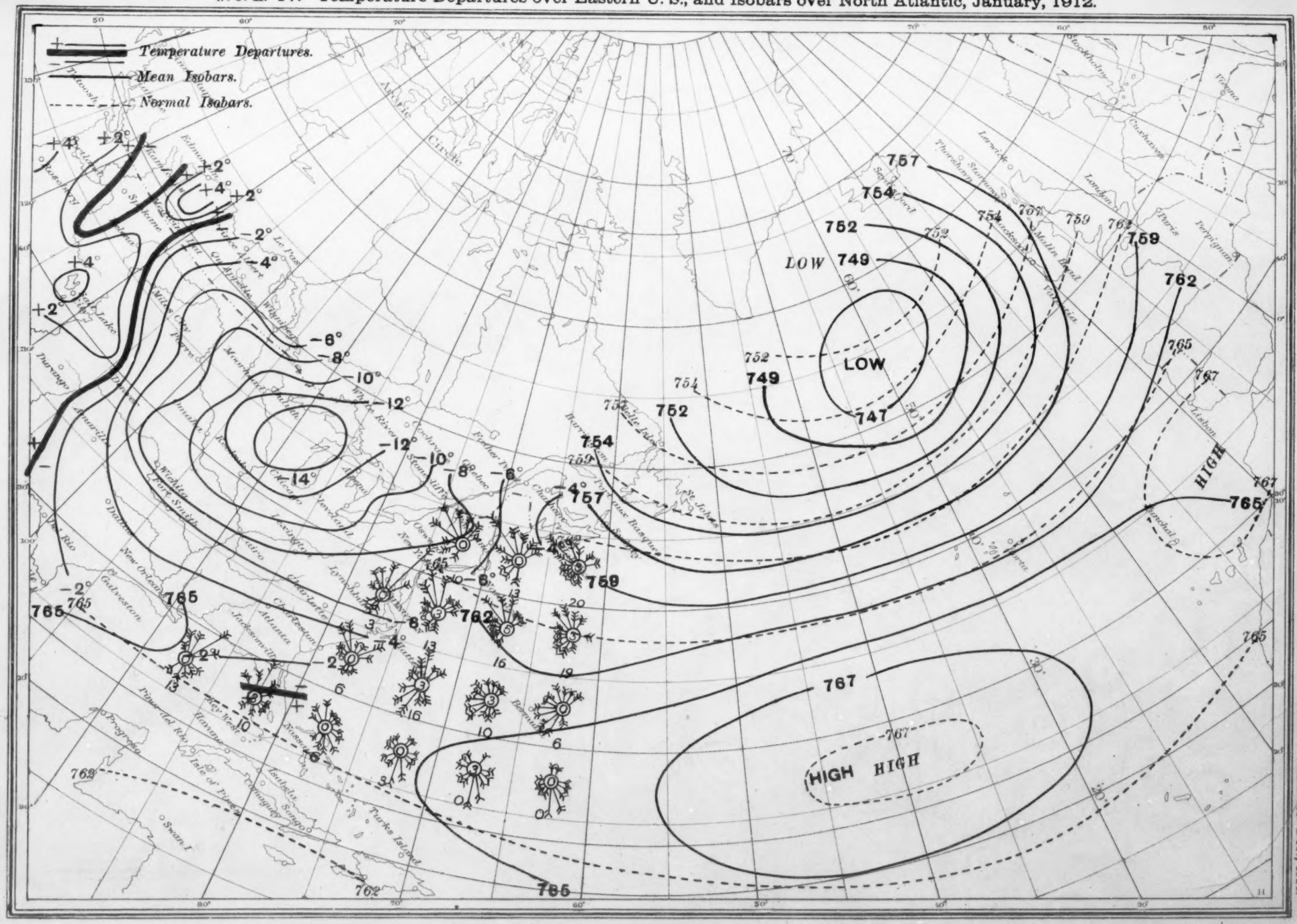


XLII–106. Dec., 1914.

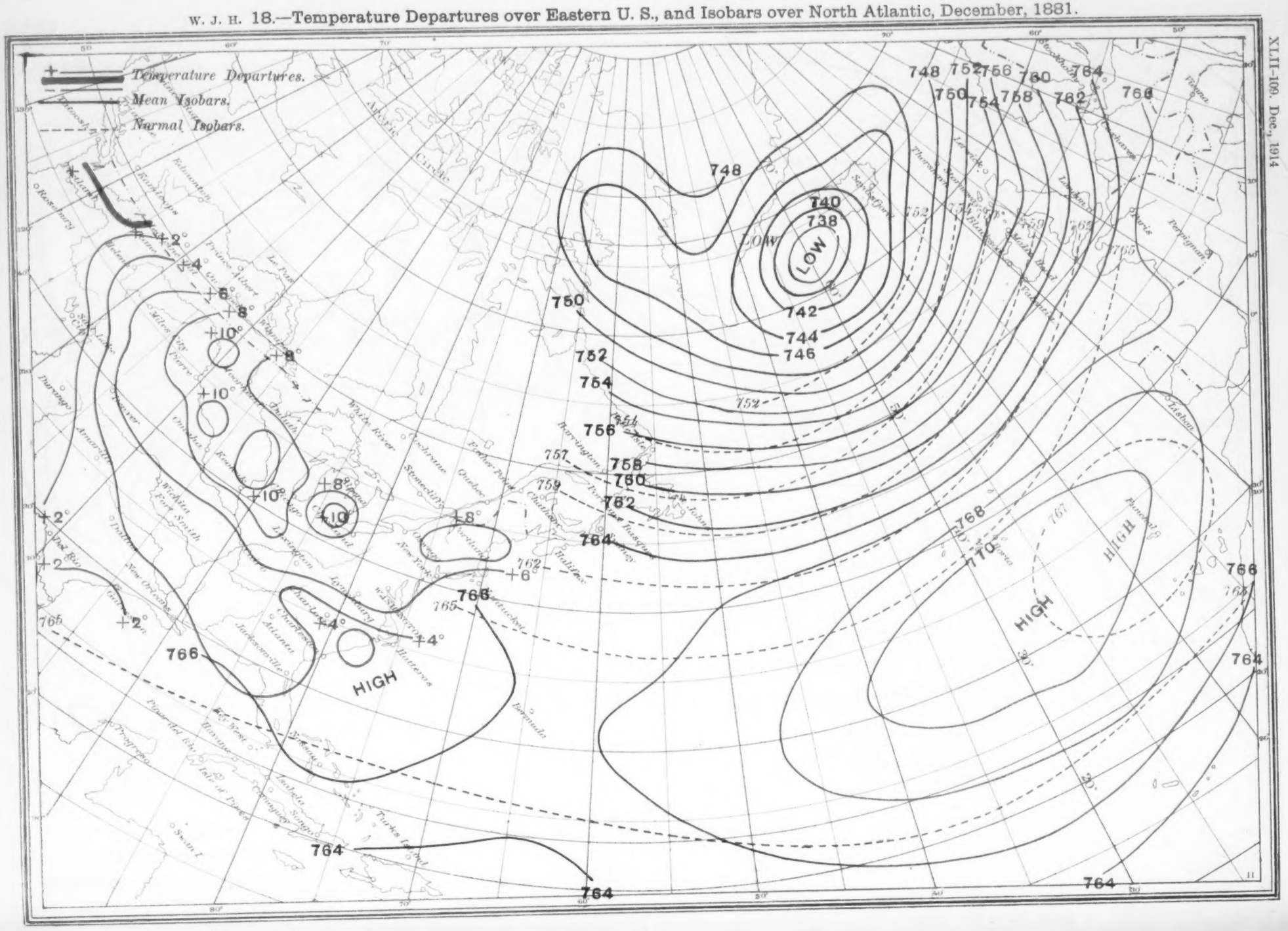
W. J. H. 16.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1905.



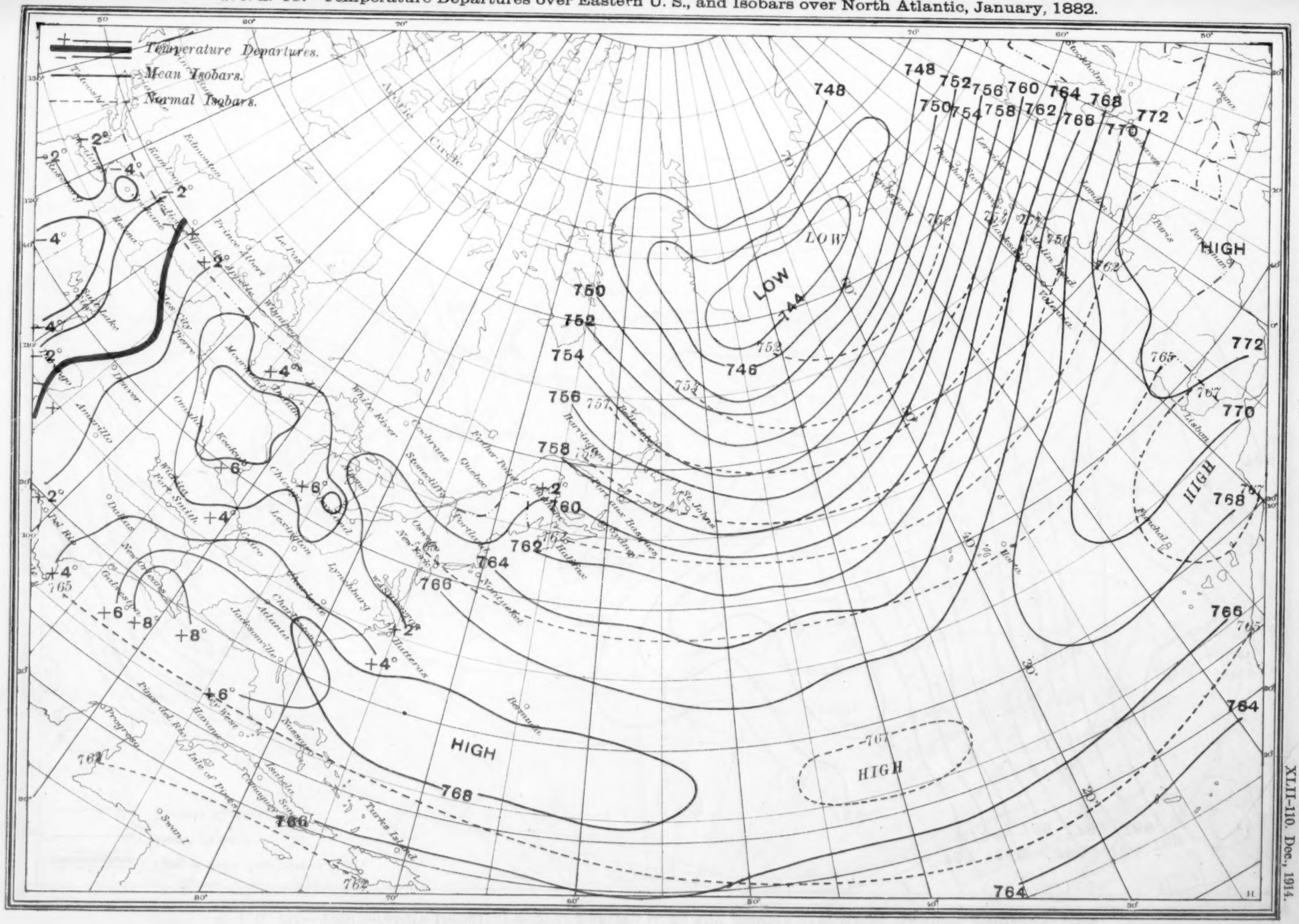
W. J. H. 17.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1912.



W. J. H. 18.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1881.

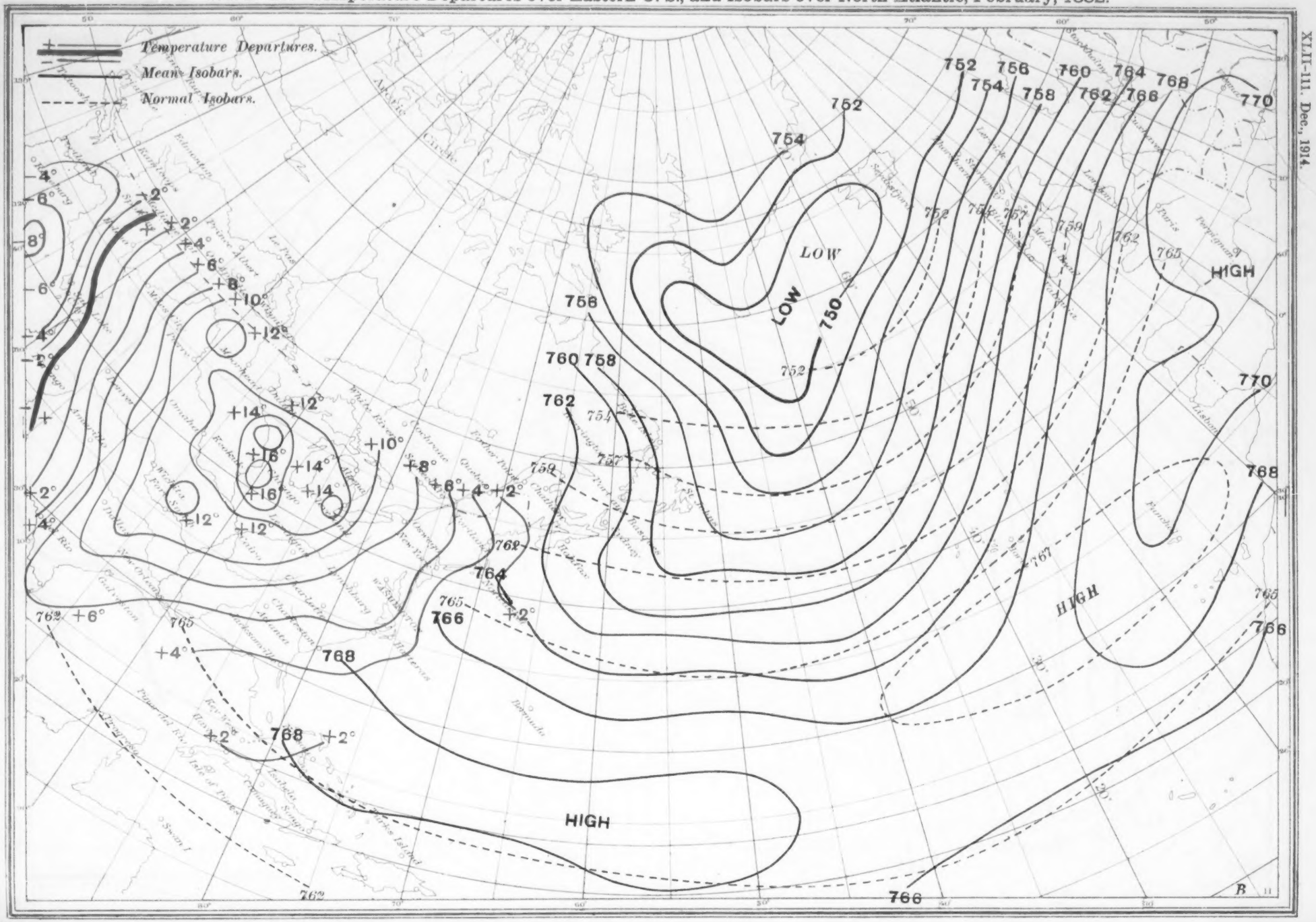


W. J. H. 19.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1882.

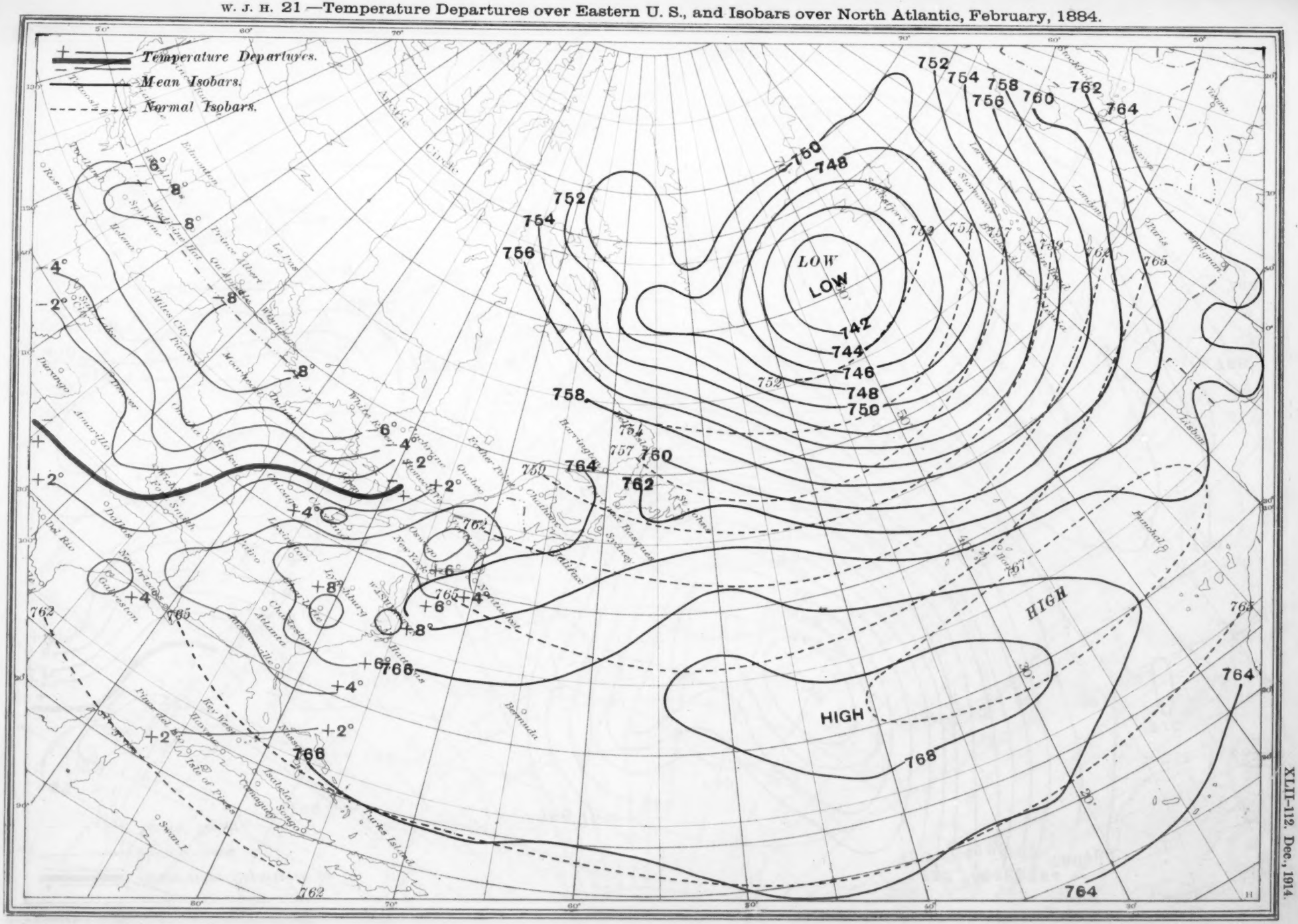


XLII-110. Dec., 1914.

W. J. H. 20.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1882.

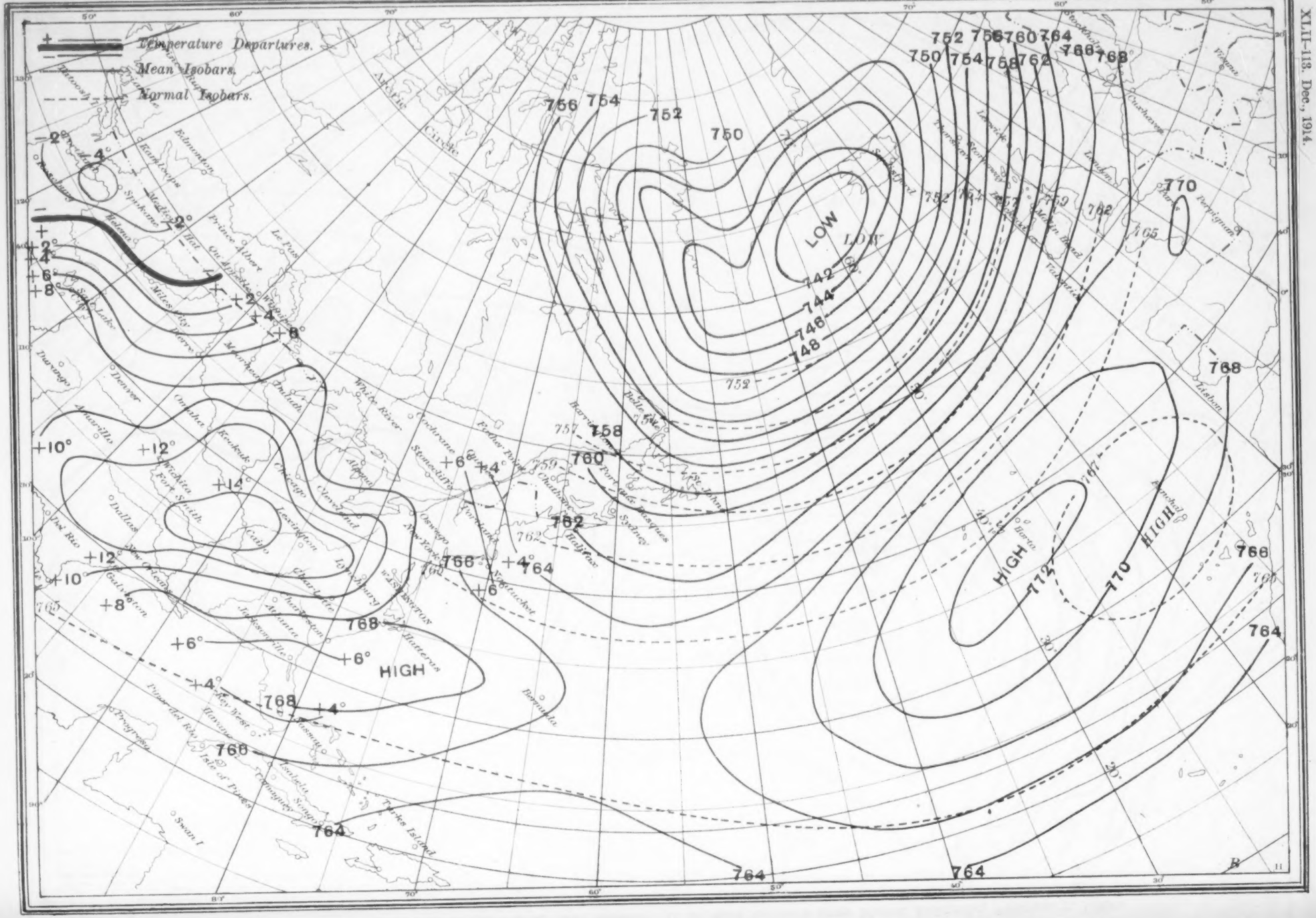


W. J. H. 21 —Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1884.



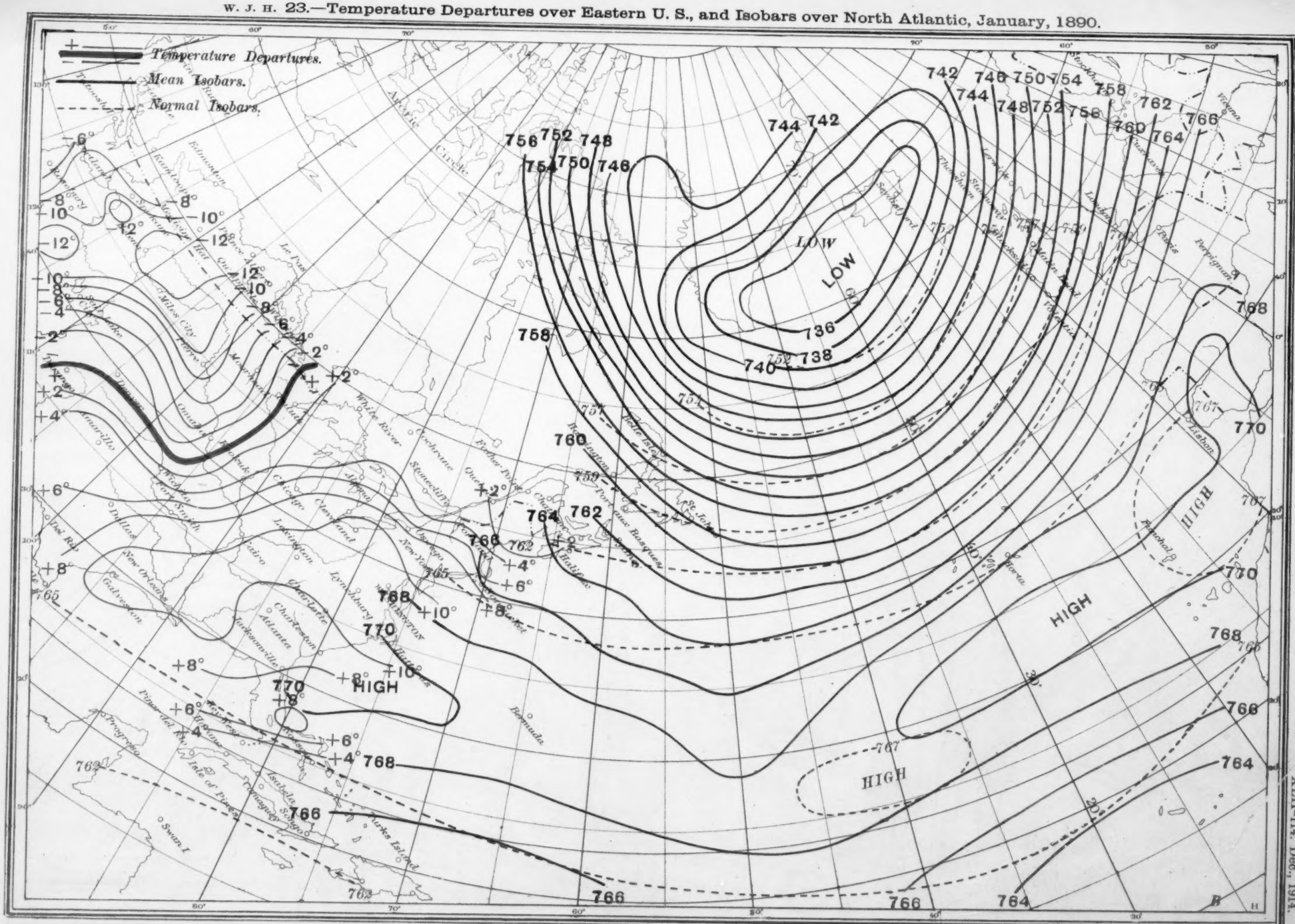
XLII–112. Dec., 1914.

W. J. H. 22.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1889.

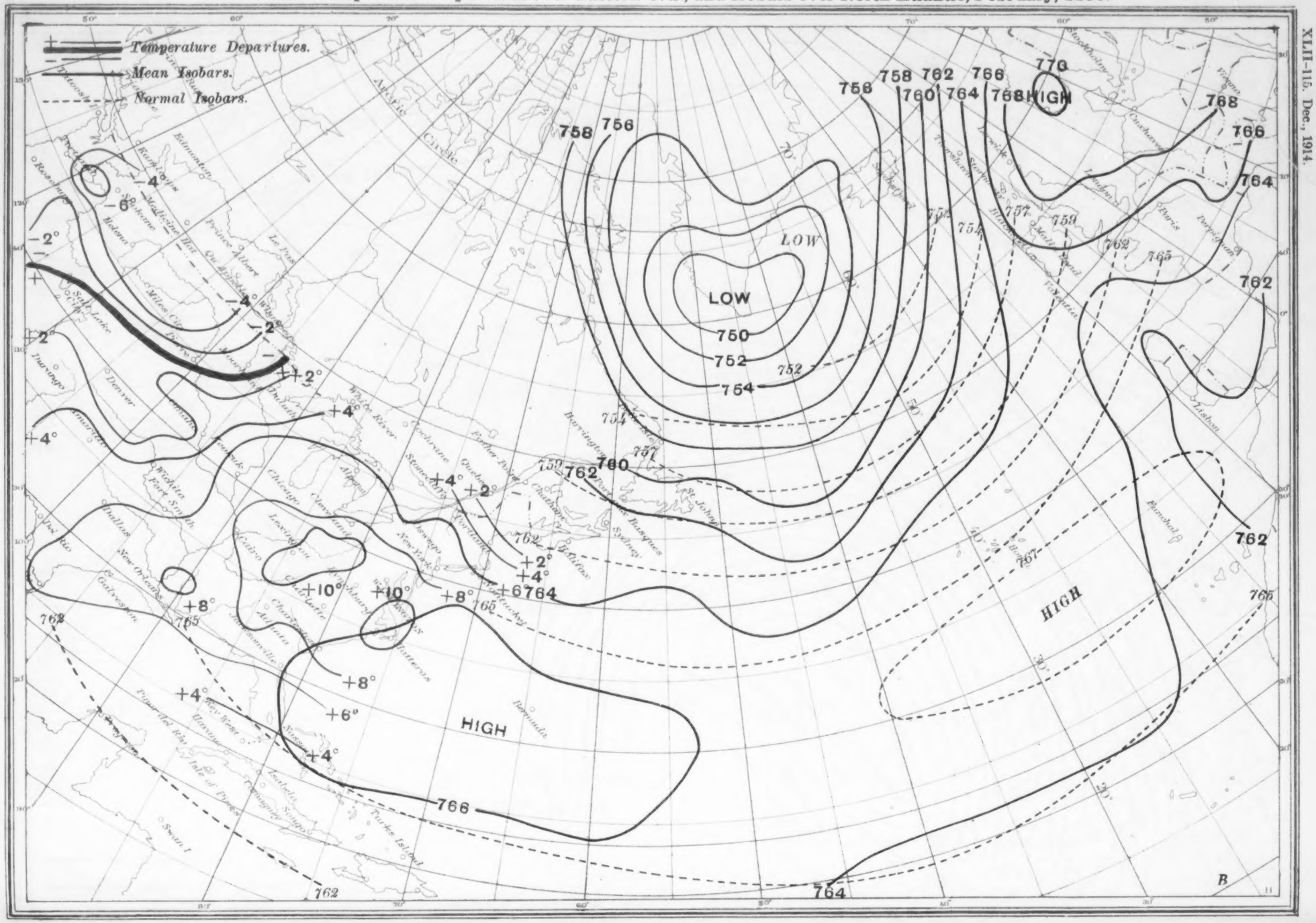


XLII–113. Dec., 1914.

W. J. H. 23.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1890.

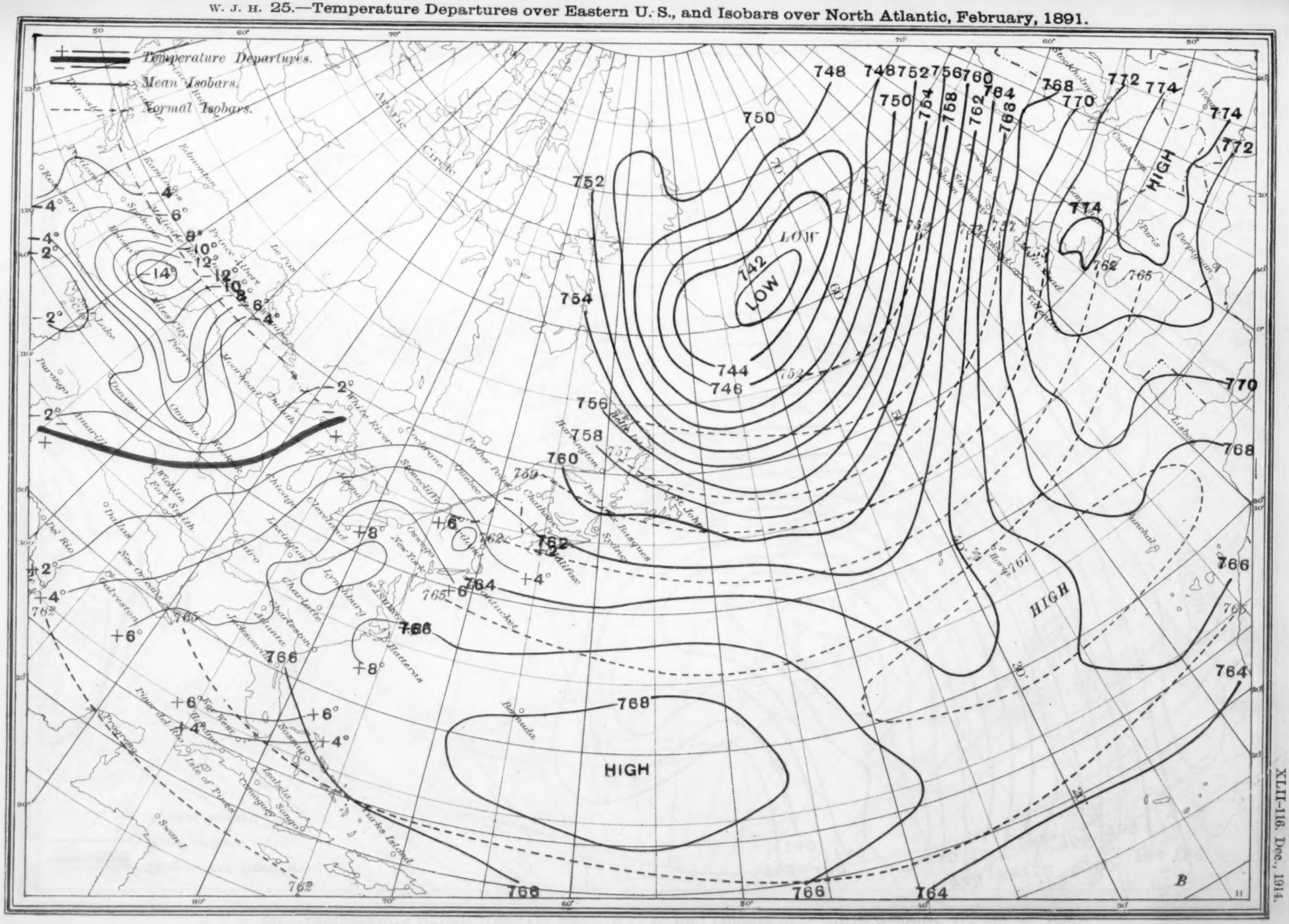


W. J. H. 24.—Temperature Departures over Eastern U. S, and Isobars over North Atlantic, February, 1890.



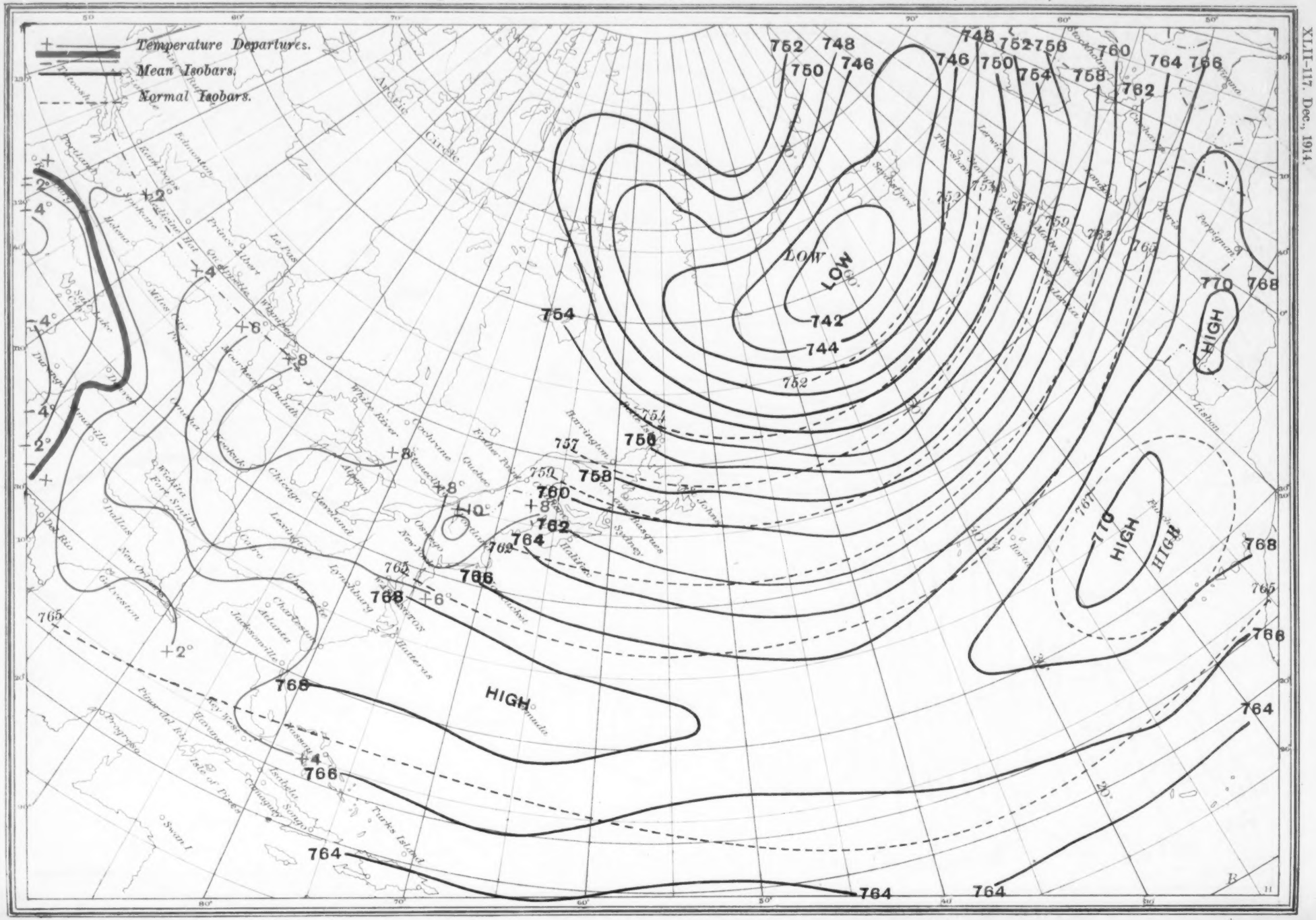
XLII-115. Dec., 1914.

W. J. H. 25.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, February, 1891.

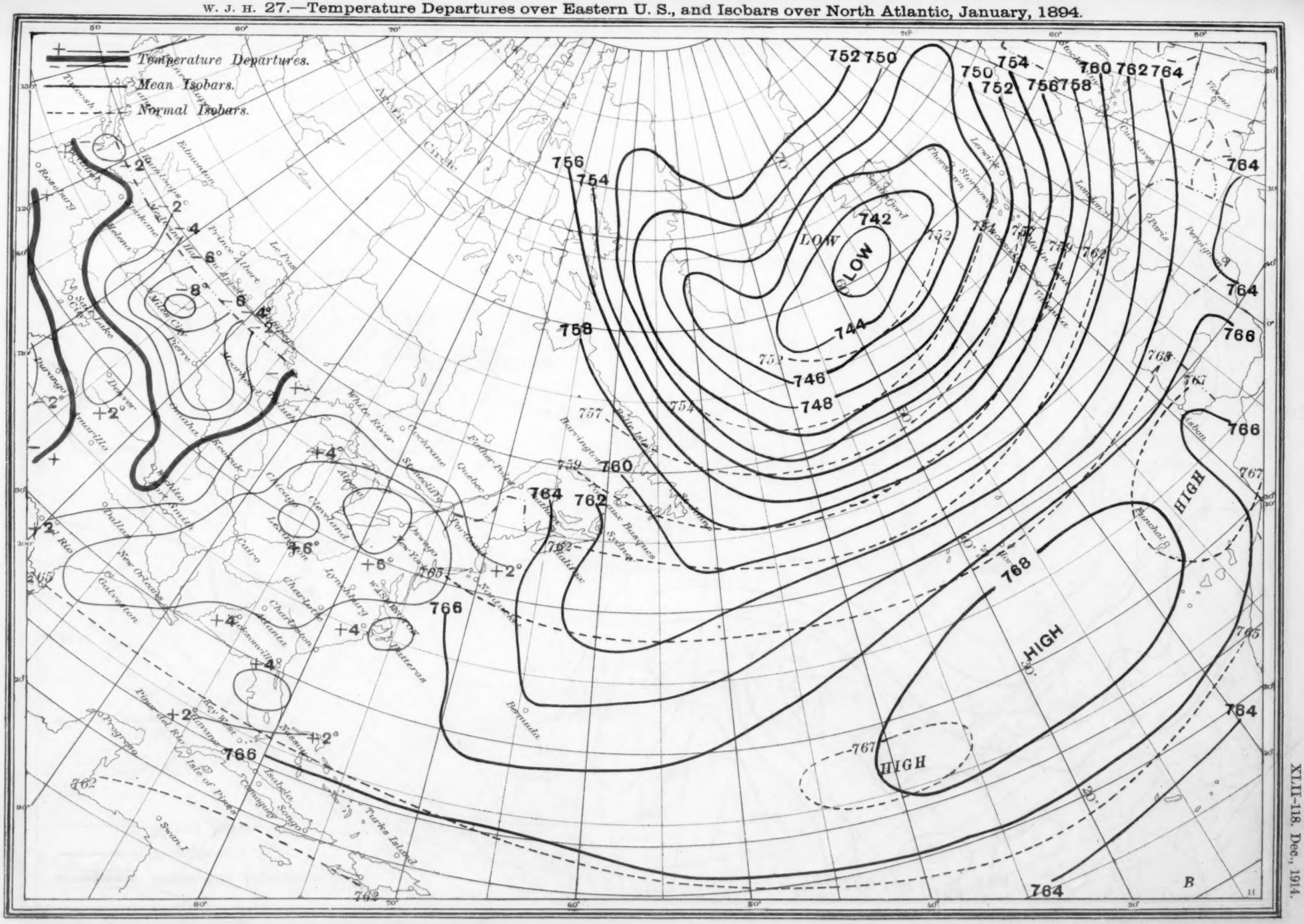


XLII–116. Dec., 1914.

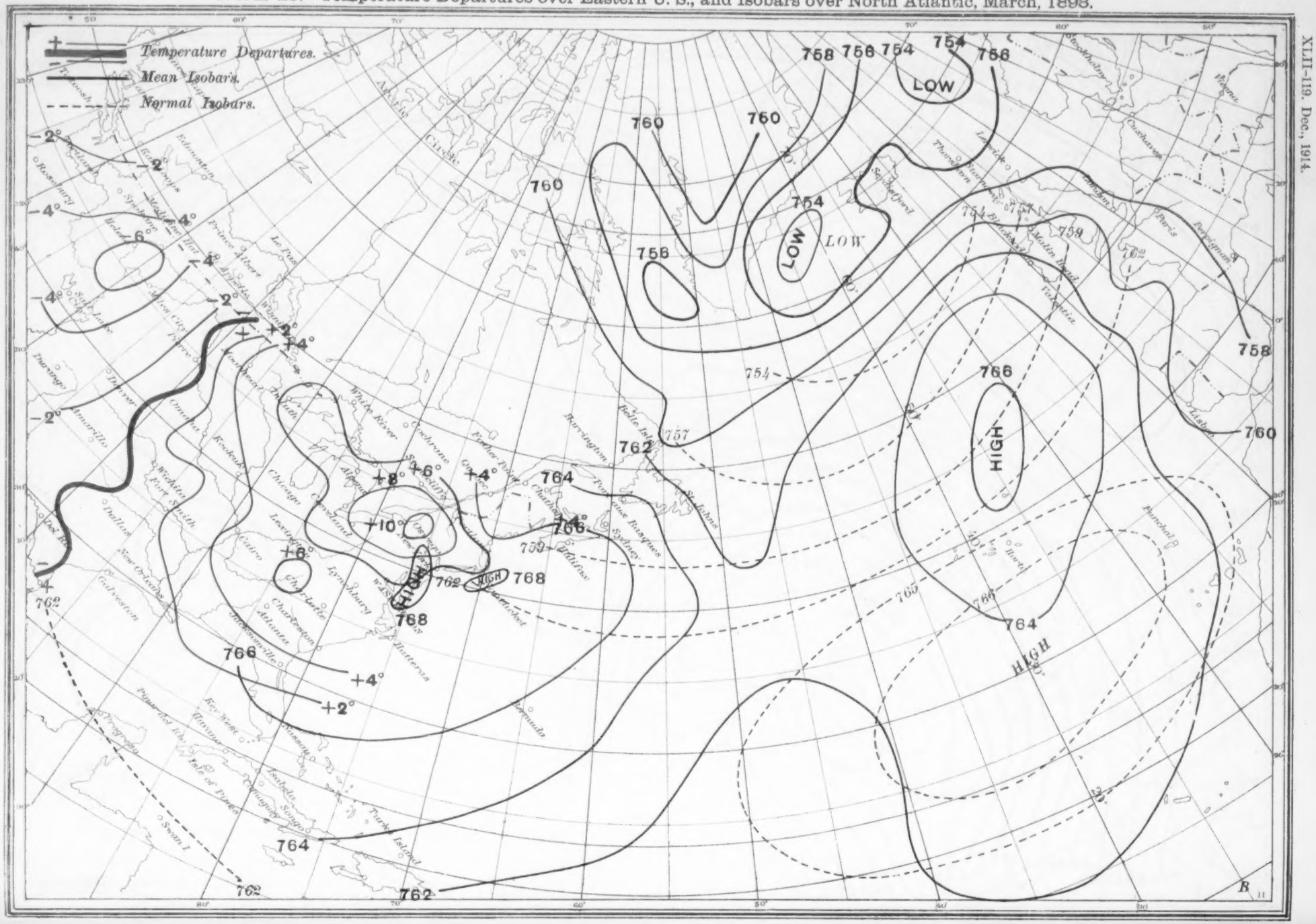
W. J. H. 26.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1891.



W. J. H. 27.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1894.

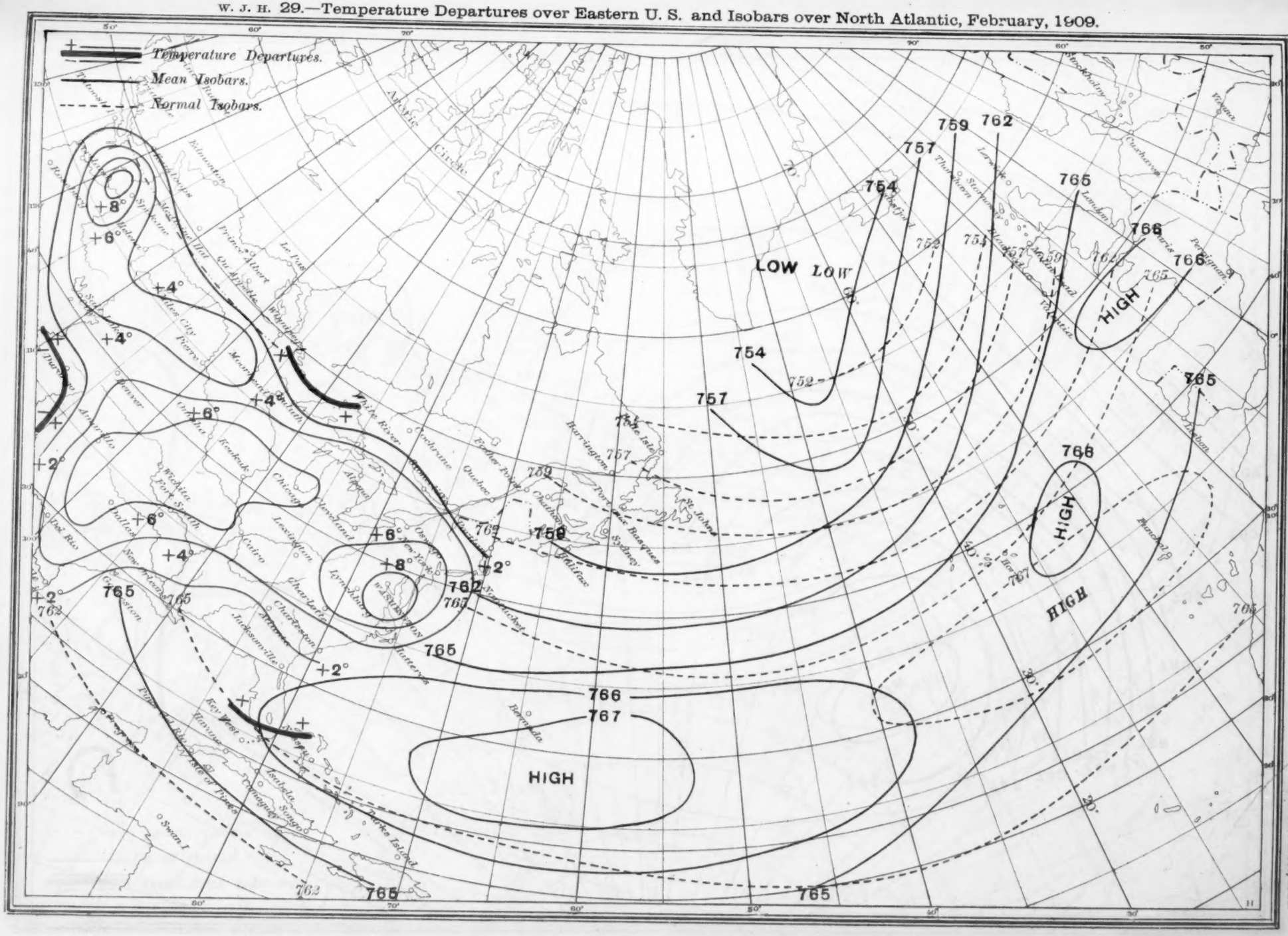


W. J. H. 28.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, March, 1898.



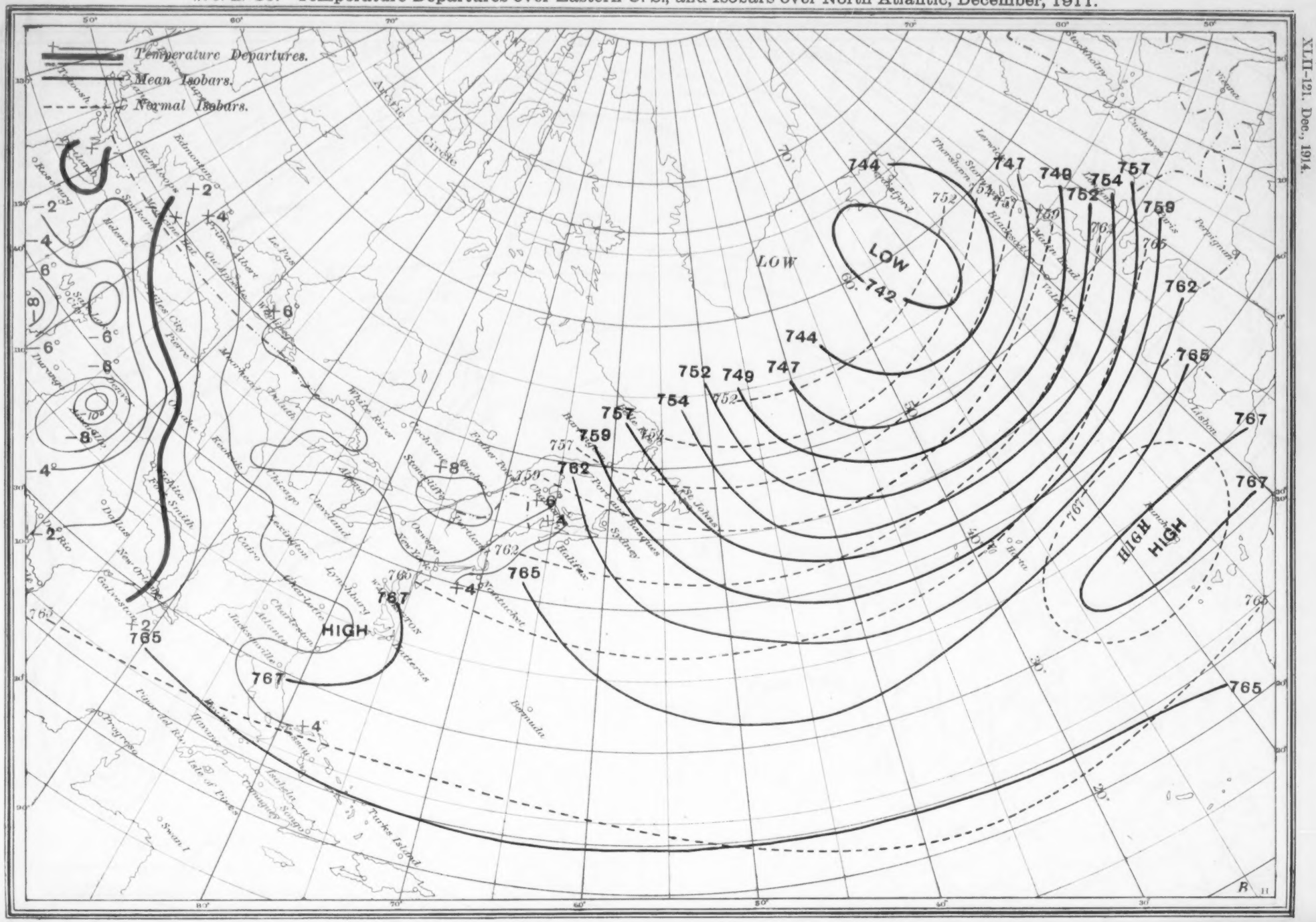
XLII-119. Dec., 1914.

W. J. H. 29.—Temperature Departures over Eastern U. S. and Isobars over North Atlantic, February, 1909.

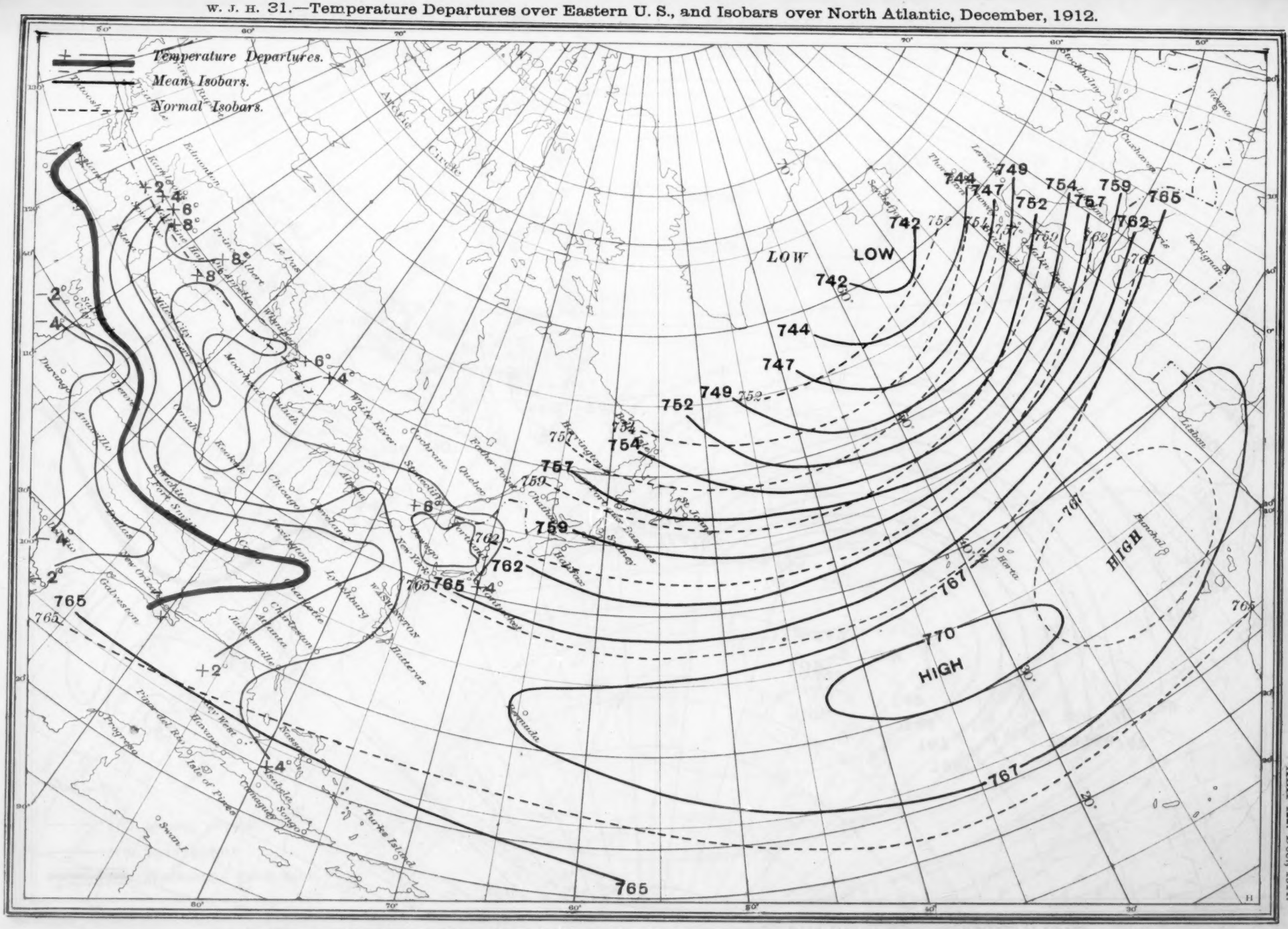


XLII-120. Dec., 1914.

W. J. H. 30.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1911.

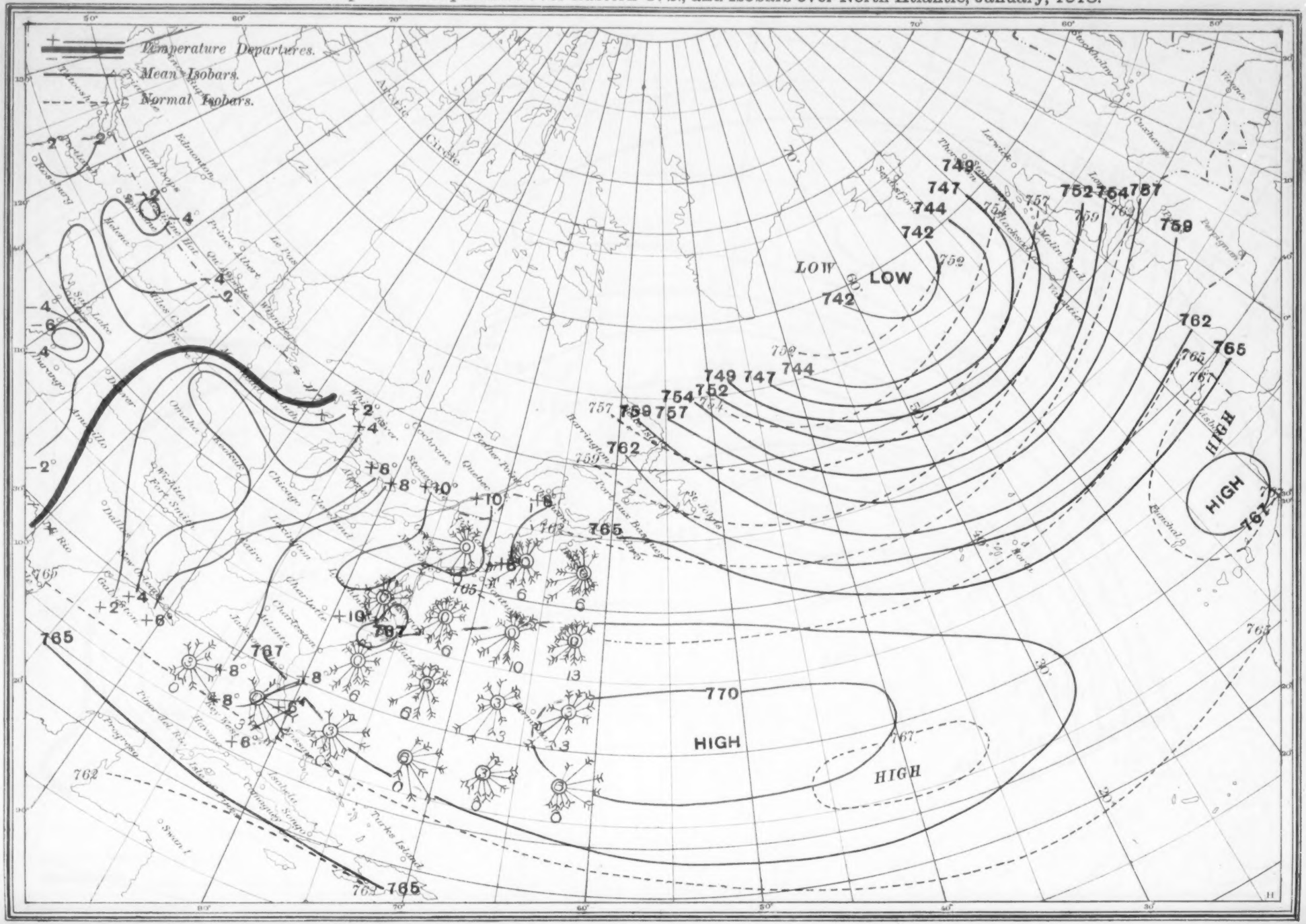


W. J. H. 31.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, December, 1912.

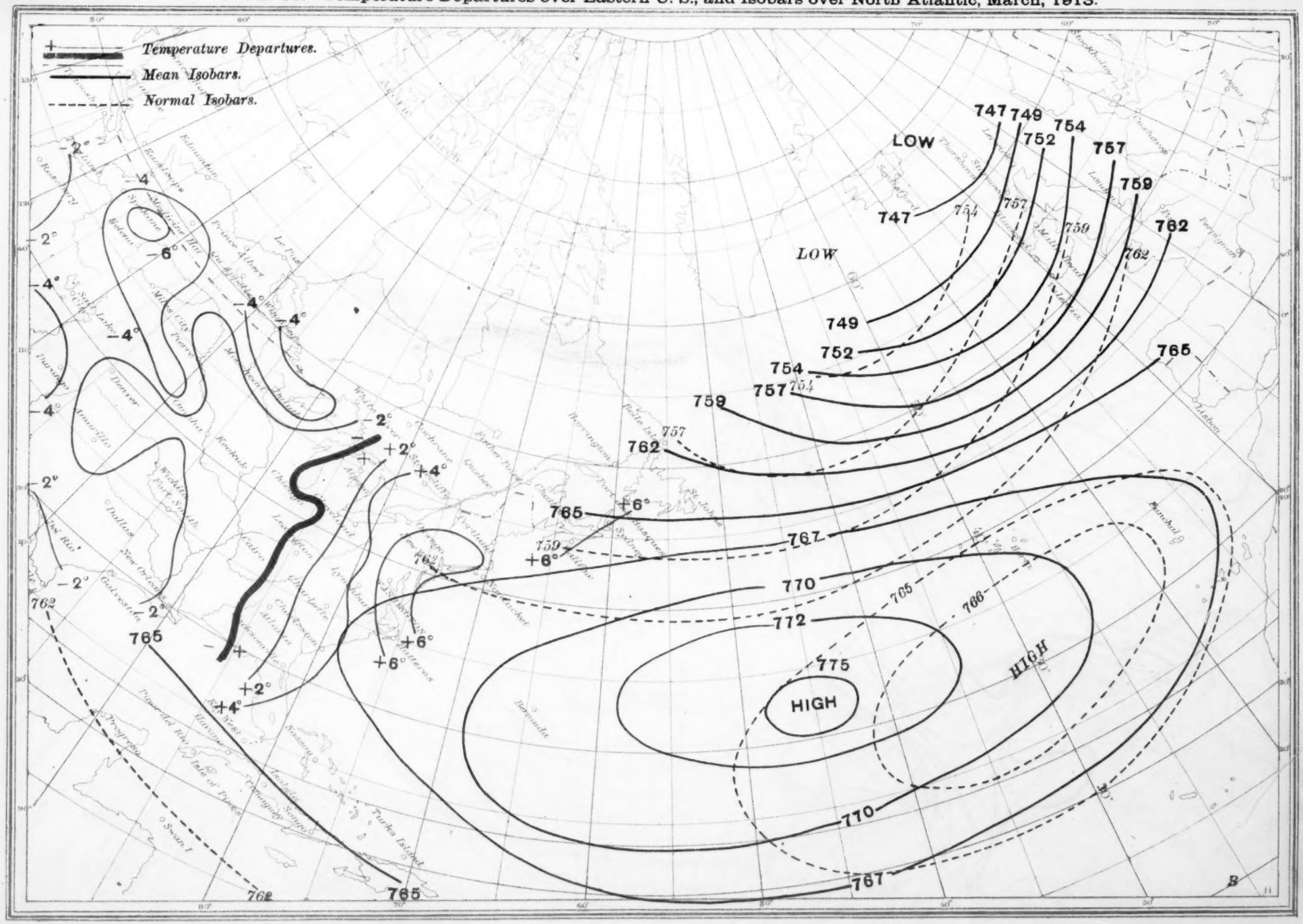


XLII-122. Dec., 1914.

W. J. H. 32.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, January, 1913.

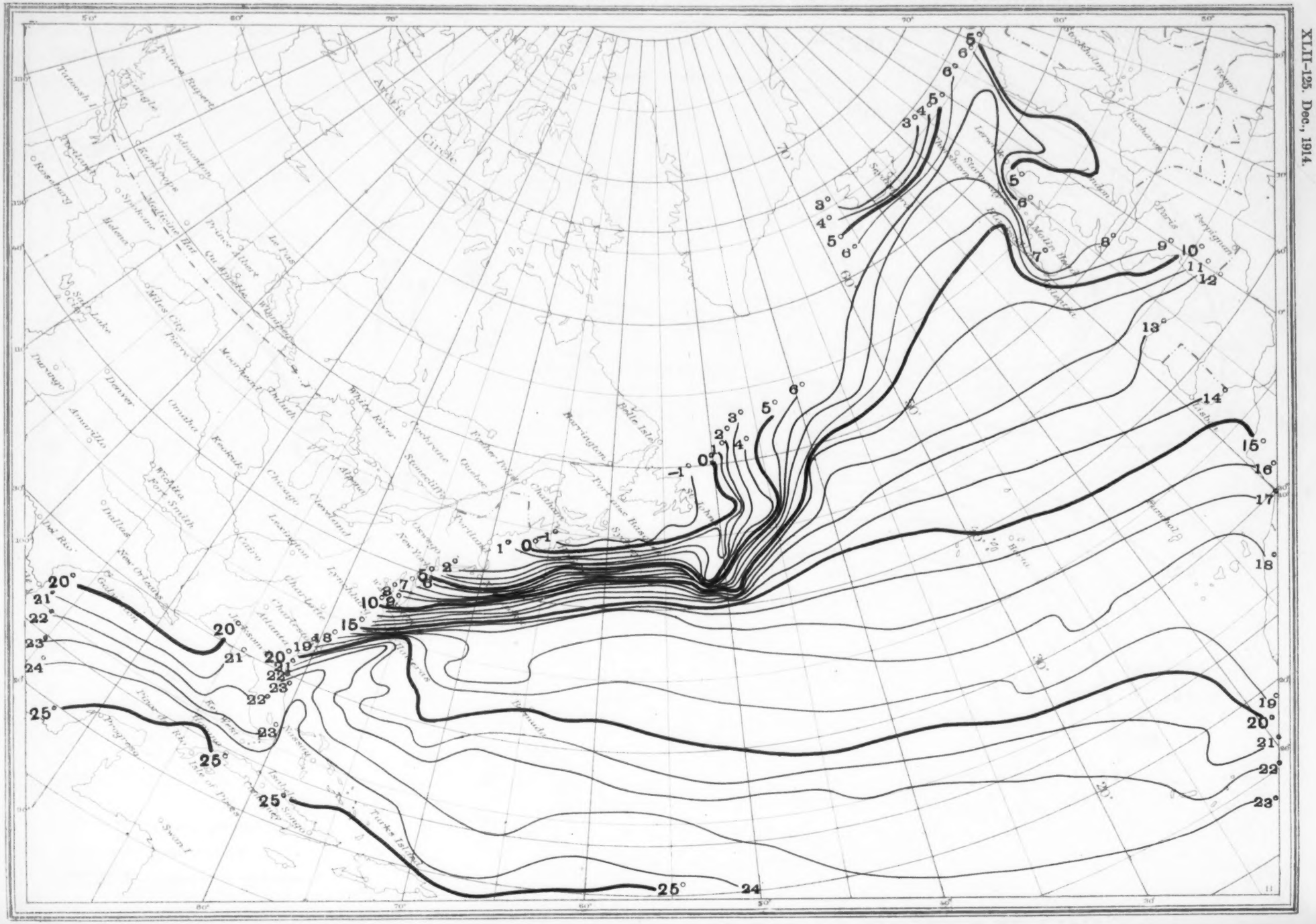


W. J. H. 33.—Temperature Departures over Eastern U. S., and Isobars over North Atlantic, March, 1913.

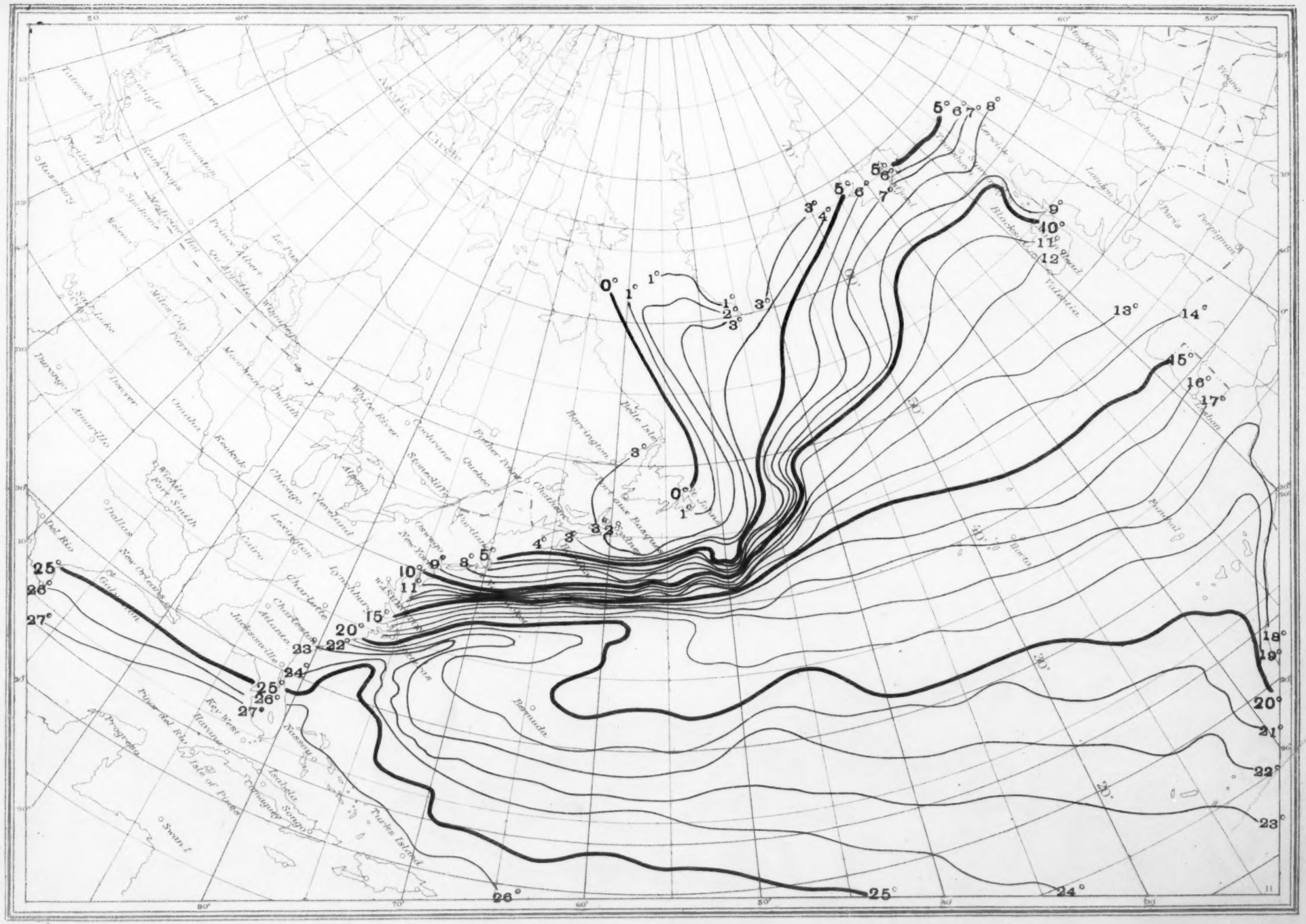


XLII-124. Dec., 1914.

W. J. H. 34.—Surface Water Temperatures, North Atlantic, February. (After Deutsche Seewarte).


Arctic Circle
Bermuda
Turks Island
Swan I
Prince Albert
Saskatoon
Edmonton
Calgary
Medicine Hat
Moosejaw
Winnipeg
Regina
Yorkton
Prince Albert
Battleford
Duck Mountain
Swift Current
Moose Jaw
Medicine Hat
Lethbridge
Great Falls
Helena
Spokane
Rosebury
Miles City
Pierre
Huron
Sioux Falls
Omaha
Denver
Amarillo
Dallas
Wichita Falls
Fort Smith
Oklahoma
Kansas City
Chicago
Cairo
Memphis
Vicksburg
New Orleans
Houston
Galveston
Austin
Abilene
Shreveport
Little Rock
Springfield
St. Louis
Indianapolis
Cincinnati
Louisville
Nashville
Atlanta
Jacksonville
Tampa
Key West
Havana
Nassau
Charleston
Wilmington
Norfolk
Washington
Baltimore
Philadelphia
New York
Albany
Buffalo
Toronto
Hamilton
Kingston
Ottawa
Montreal
Quebec
Portland
Boston
Halifax
St. John
Fredericton
Sydney
Port aux Basques
Port aux Basques
Battle Isld
Farrington
Belle Isle
Labrador
Hopedale
Nain
Okkak
Hebron
Ungava
Port Burwell
Port Stanley
Port Colborne
Port Dover
Port Hope
Toronto
Kingston
Ottawa
Montreal
Quebec
Portland
Boston
Halifax
St. John
Fredericton
Sydney

W. J. H. 35.—Surface Water Temperatures, North Atlantic, May. (After Deutsche Seewarte).



XLII–126. Dec., 1914.

551.55
ic

MAR 22 1915
Univ. of Mich.

W. B. No. 543

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 42, No. 12

DECEMBER, 1914

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

DECEMBER, 1914.

CONTENTS.

	Page.
INTRODUCTION	647
SECTION I.—AEROLOGY:	
Solar radiation intensities at Washington, D. C., during October, November, and December, 1914. H. H. Kimball.	648
Photometric measurements of daylight illumination on a horizontal surface at Mount Weather, Va. H. H. Kimball	650
Heat from the stars	653
Kron on the extinction of light in the terrestrial atmosphere in the region of the ultra-violet	653
SECTION II.—GENERAL METEOROLOGY:	
Present status of our knowledge of the causes of the diurnal changes in temperature, pressure, and wind. J. M. Pernter	655
On Thunder. Wilhelm Schmidt	665
Place of Forestry among the natural sciences. H. S. Graves.	671
Warm and cold winters of the eastern United States. W. J. Humphreys. (35 charts)	672
International simultaneous observations	675
Do clouds yield snow easier than rain? D. F. Manning	676
Foreign distribution of the MONTHLY WEATHER REVIEW during 1914-15	677
SECTION III.—FORECASTS:	
Storms and warnings for December. E. H. Bowie	678
SECTION IV.—RIVERS AND FLOODS:	
Rivers and Floods, December, 1914. A. J. Henry	680
Snowfall at high altitudes, December, 1914	680
Lake levels during December, 1914	682
Floods in New England Rivers. A. J. Henry	682
SECTION V.—SEISMOLOGY:	Page.
Resumption of seismological work. C. F. Marvin	687
Seismology. W. J. Humphreys	687
Seismological reports for October, November, and December, 1914	689
SECTION VI.—BIBLIOGRAPHY:	
Recent additions to the Weather Bureau Library. C. F. Talman	690
Recent papers bearing on meteorology and seismology. C. F. Talman	690
Notes from the Weather Bureau Library. C. F. Talman	692
SECTION VII.—WEATHER AND DATA FOR THE MONTH:	
Weather of the month. P. C. Day	693
Tables—	
Description	696
I. Climatological data for United States Weather Bureau stations	697
II. Accumulated amounts of precipitation	700
III. Data furnished by the Canadian Meteorological Service	702
Charts—	Chart.
I. Hydrographs, December, 1914	84
II. Tracks of centers of highs	85
III. Tracks of centers of lows	86
IV. Departures of mean temperatures	87
V. Total precipitation for the month	88
VI. Percentage of clear sky	89
VII. Sea-level isobars and isotherms and prevailing winds	90
VIII. Total snowfall for the month	91
W. J. H. 1—35	92—126

NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., September) should be in the hands of the Editor before the end of the next following month (e. g., October), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically requested when the manuscript is submitted.

Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing on meteorology, addressed "Library, U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology may be as complete as possible.

BACK NUMBERS.—Recipients who do not wish to retain this or other publications of the Weather Bureau will confer a favor by notifying the "Chief of Bureau," who will take action to secure their return.

As the surplus of MONTHLY WEATHER REVIEW SUPPLEMENT No. 1, recently issued, is limited, recipients who do not care to retain their copy will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

Copies of this Monthly Weather Review may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 25 cents each; subscription price, per volume, $2.50.